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EXPLAINING THE EFFECTS OF STIMULUS RESTRICTION: TESTING THE DYNAMIC HEMISPHERIC ASYMMETRY HYPOTHESIS

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Abstract

The Restricted Environmental Stimulation Technique (REST) has been used in hundreds of studies investigating the effects of drastically reducing the accustomed flow of ambient information and stimulation. Some of this research has explored changes in basic psychological and psychophysiological processes; other portions have been directed toward the application of REST, especially in clinical and health psychology. Although a substantial data base now exists, no adequate theoretical explanation has been offered for the wide range of consistent and striking effects of REST on human beings. This paper describes several original experiments, and reviews the literature, assessing the evidence relevant to one promising explanation: the Dynamic Hemispheric Asymmetry (DHA) model, which proposes that in REST the normally non-dominant cortical hemisphere becomes more active and exerts greater influence over cognitive and affective processes. Research bearing upon the hypothesis includes work on memory, learning, imagery, divergent thinking, creativity, perception, habit modification, attitude change, hand dominance, and brain activity. The results offer only mixed support for the DHA model, but indicate areas for theoretical extensions and further research.

Theories of REST

It is a cliché that human beings chronically function under constant stimulus bombardment, and that coping with ambient information and stimulation is the major demand on our attention, perception, cognition, and emotions. For these reasons, and also because of the adverse effects of the often excessive demands of such coping, a long line of research has been directed at understanding the effects of a temporary, drastic reduction in the level of environmental input. Techniques for achieving this level of stimulus reduction have had many labels, including perceptual isolation and sensory deprivation; the most commonly used term currently is Restricted Environmental Stimulation Technique, or REST (Suedfeld, 1980). In the growing literature on clinical and health applications of the technique, the T sometimes stands for Therapy.

Although the first studies of the effects of profound stimulus reduction on human beings were published in the 1950s, the first authoritative overview of the research appeared 15 years later (Zubek, 1969*a*). In that book, one of the shortcomings of the field was said to be that researchers had generated many facts, but had failed to propose and test a theory that would explain the wide-ranging and impressive changes in functioning that were evidenced during or after REST.

Following Zubek's book almost a decade later, Suedfeld (1980) noted that at that point there were even more facts, and also many theories, but there still was no solid body of empirically confirmed theory by which to interpret those facts. Many theories explained some portion of the findings, frequently the same portion as other theories; but none explained the entire set of results. There was also a lack of approaches specific enough to identify the foundation for testing alternative hypotheses so that theoretical formulations could be evaluated in competition with each other. Because REST has reliable and sometimes dramatic effects on such a broad array of human functions, finding an adequate theoretical explanation is an intriguing scientific task. In addition, REST has also been identified as a potent tool in health enhancement, psychotherapy,

and the improvement of athletic skills. The fact that it is less widely used by practitioners than other methods whose empirical support is less persuasive (or, at best, no more persuasive) has been attributed in part to the lack of a comprehensive conceptual framework whereby the effects can be understood. Thus, a good theory would benefit practitioners and clients as well as researchers.

Neurophysiological and neuropsychological models have been among the earliest to try to explain REST effects. This primacy is understandable: the technique was first invented (Solomon *et al.*, 1961) to test aspects of Hebb's theoretical Conceptual Nervous System (1955). A number of early formulations are presented and assessed in Zuckerman (1969*a*): in general, the brain structures thought to be involved in mediating REST effects were the hypothalamus and the reticular system, and the theorists were interested in explaining known REST effects rather than generating new hypotheses to be tested.

Perhaps the most influential of the early neuropsychological theories was that of Lindsley (1961), who suggested that sensory deprivation, overload, and distortion modified the functioning of the ascending reticular activating system (ARAS), which organizes and transmits inputs to the cortex. Somewhat later, Schultz (1965) proposed that stimulus reduction affects not only the ARAS but also the hypothalamus, which is responsive to cortical as well as sensory stimuli, and that both structures are involved in maintaining an optimal level of sensory variation. Schultz called this maintenance 'sensoristasis', as an analogue of homeostasis. Other theorists (e.g. Jones, 1969; Zuckerman, 1969*a*; Lilly, 1977) accepted the idea of homeostasis-like mechanisms that in REST conditions lead to stimulus hunger. There is no neurological evidence to verify that either the ARAS or the hypothalamus shows functional changes during or after REST, or that any such change (had it occurred) would have been related to the hypothesized information-oriented drive state.

A more elaborated neuropsychological model of REST effects could be based upon the three functional brain units proposed by Luria (1973). These units govern activation, information processing and regulatory activity. Anatomically, they involve most parts of the brain and behaviourally, most aspects of cognition, memory, investigative activity, information storage, and stimulus–response links. Although the implications of the model for REST have been noted (Suedfeld, 1980), no research has been conducted to explore them. In fact, until recently the understanding of brain functioning and brain–behaviour connections was such that using them to explain REST effects was to try clarifying one mystery by citing another, probably even less well-understood one (Suedfeld, 1969*a*, 1990*a*).

The Hemispheric Specialization Model

Starting in the 1960s, Sperry and his colleagues (see Sperry, 1985) first impressed upon scientists and the lay public that the two hemispheres of the cerebral cortex had significantly different roles in governing behaviour.[2] A flood of other research followed the original demonstrations, extending a model developed from studying brain-damaged patients to explain normal brain–behaviour relations. The rough distinction between the supposedly 'linear' information processing style of the dominant (D) hemisphere—the left hemisphere, in most people—as opposed to the 'holistic' style of the non-dominant (ND) hemisphere, was almost instantly accepted as an overarching law, particularly by people not aware of all of the exceptions, qualifications, and limitations in the data. There was increasing evidence of some specificity in the functioning of the two hemispheres, even if the evidence was not as unassailable, and the specificity not as clear-cut, as the popular press indicated. In general, these distinctions include D hemisphere specialization in verbal, abstract, logical, sequential, analytic and objective thinking and ND hemisphere tendencies toward holistic and intuitive modes, spatial relationships, and non-verbal visual and auditory tasks (e.g. Gazzaniga, 1978; Sperry, 1985).

The DHA Model and REST

The earliest theoretical link between hemispheric specialization and REST was proposed by Wickramasekera (1978), who hypothesized that the critical, analytical functions of the D hemisphere are temporarily inhibited by lowered arousal. This inhibition would allow the emergence of the ND hemisphere's holistic functions. Wickramasekera listed 'sensory deprivation' as among the situations that result in markedly lowered arousal and can therefore be expected to have these effects.

Soon after, Reed (1979) proposed that the changes induced by REST parallel the functions of the ND hemisphere, and suggested that 'SD [sensory deprivation] conditions may in some way facilitate activity of the right hemisphere whilst inhibiting that of the

left' (p. 174). He indicated that the mechanism through which this may occur was unknown, but speculated that the reduction of meaningful input coupled with instructions that discouraged verbalization may encourage imaginal, while inhibiting verbal, modes of processing.

Budzynski (1990) elaborated the theory that a variant of the hemispheric specialization model may explain REST effects. This variant is the *Dynamic Hemispheric Asymmetry (DHA)* model of brain functioning: the idea that the two cortical hemispheres govern different kinds of cognitive and other behaviours, that the dominance–non-dominance relationship between them is variable, and that one source of such variation may be an interruption of 'normal' levels of ambient stimulation and information. Budzynski (1976) had also suggested that REST and related techniques, such as meditation, induce a 'twilight state of consciousness' marked by increased theta activity. This EEG phenomenon has been confirmed by several REST studies (e.g. Saunders & Zubek, 1967; Zubek, 1969*b*; Turner, 1993).

The DHA model accepts the view that the two hemispheres have the potential for independent changes in activation level (Levy & Heller, 1983) and that they also have independent access to cognitive and attentional resources (Wickens & Mountford, 1981; Friedman & Polson, 1982). For example, traumatic memories encapsulated in unconsciousness by defence mechanisms are thought to be stored in the ND hemisphere, and to become more accessible to conscious attention when that hemisphere is relatively dominant (Budzynski, 1990).

According to Wickramasekera, Reed, and Budzynski, REST may enhance the activity of the normally ND cortical hemisphere in relation to the normally D hemisphere. How or why should this happen? There are several possibilities, two of which focus on changes in D hemispheric activity regardless of changes in the ND hemisphere. First, it may be that the D hemisphere processes, and perhaps requires, a constant input flow to maintain its level of activity and with that, its dominance. If this flow is seriously impeded, as in REST, both the level of activity and the dominant role in guiding cognition and behaviour are diminished. The ARAS may actually play the mediating role proposed by Lindsley (1961), in not continuing to keep the cortex sufficiently active. Another explanation, by no means mutually exclusive, is that the D hemisphere is adapted to coping with the continuous challenges posed by a dynamic environment; when the challenges and the need for coping diminish, as they do in REST, the hemisphere partially shuts down. In both cases, the ND hemisphere would become relatively more salient, even with no absolute change in its own activity level.

However, it is not necessary to assume that ND activity remains stable. In an environment as novel, formless, and unstructured as REST, where linear and logical thought may not be an effective coping strategy, the activation level of the ND hemisphere could actually increase. Obviously, such an increase could coincide chronologically with deactivation of the D hemisphere, as outlined above. Still another possibility is a decrease in the activation level of the entire cortex (as Lindsley's ARAS hypothesis suggests), but starting earlier in the D hemisphere and/or progressing at different rates so that the activation gradients approach each other. In fact, Budzynski's summary of the DHA explanation of REST effects is: 'REST will produce a decreasing arousal, a decrease in D functioning, and an increase in relative ND dominance' (1990, p. 14). Note that it is not necessary to posit that the gradients actually cross. The D hemisphere may remain dominant—only perhaps not *so* dominant. As we shall see, the three general effects predicted above give rise to a longer list of specific, testable predictions.[3]

Hypotheses from the Early Theories

What hypotheses can be derived from the early neuropsychological theories? Most of them were directed more toward explanation than toward prediction; that is, they account for data that had already been reported at the time the theory was published. Among the few actual predictions, most lacked specificity. Perhaps the major exception is Lindsley's ARAS-based model (1961), which has three major implications concerning the effects of REST: (a) 'Stimulus hunger' resulting in the enhanced acceptability or attractiveness of stimuli (whether endogenous or ambient) that would normally be ignored or dismissed; (b) Deactivation, boredom, and sleep if stimulus reduction continued; and (c) Central regulation to maintain an even level of cortical and reticular activity ('centrifugal afferent control', Lindsley, 1961, p. 184).

Of these, the first hypothesis is partially supported by data. In general, REST subjects do accept and attend to stimuli that they might normally overlook. Part of this can be simply explained by lowered sensory thresholds (Suedfeld, 1980); however, for more complex inputs, 'stimulus hunger' may actually be information hunger. As Jones

(1969) first showed, and several other investigators confirmed, stimulation level *per se* is less important than information value. These findings would not have been predicted by Lindsley's theory. Further, the desire to receive stimulation does not necessarily lead to better memory for that information, so that the degree of increased attention is dubious (reviewed in Suedfeld, 1980). Stimulus hunger and its behavioural consequences form the essential testable derivations from some of the other theories mentioned above—for example Schultz' and Zuckerman's—so that the paucity of empirical confirmation applies equally to those theories.

As for deactivation, the evidence favours oscillating arousal throughout long chamber-REST sessions, with relaxed alertness rather than boredom characterizing the shorter sessions used in flotation REST. Although chamber subjects sometimes report having slept for long periods, there is no good objective verification of this claim. It may well be that the REST participant is not a good judge of the proportions of awake, asleep, hypnagogic, and intermediate states experienced in the environment. Another theory of deactivation (Gellhorn & Loofbourrow, 1963) suggests that drastic stimulus reduction lowers hypothalamic reactivity. In a comfortable environment with minimal stimulation, this change should lead to a pleasant state of deep relaxation. In contrast to early reports, recent findings (especially with flotation REST) support this prediction; but relaxation in REST can be explained without reference to the hypothalamus, and there is no direct neurological evidence to link the two. Worst of all, given the wide array of known REST effects, such a one-hypothesis theory is at best lacking in power. Thus, whether or not it is correct as far as it goes, it seems to be a dead end.

There is no evidence bearing upon the third Lindsley hypothesis. Like the other neuropsychological explanations offered in the 1950s and early 1960s, a test requiring neurophysiological measures has never been performed. When these theories were first proposed, the equipment needed for such relatively complex brain–behaviour studies was not available; now that the apparatus exists, attention has shifted to cognitive theories and even more to essentially atheoretical applied research.

Hypotheses from DHA Theory

Unlike the earlier theorists, those working in the context of hemispheric dominance have derived some specific, testable predictions. The most detailed of these have been Budzynski's hypotheses, presented with the DHA model. Moreover, unlike those based on other neuropsychological models, the DHA-based hypotheses are not all obvious, nor do they only explain already reported data. These hypotheses include (Budzynski, 1990; explanations added):

(1) The emergence of the ND hemisphere will enhance the accessibility of normally unconscious processes, such as early, sometimes even traumatic and repressed, memories. This is predicted because such memories are frequently stored non-verbally in the ND hemisphere.

(2) For reasons that reflect the basic tenet of the theory, an ND hemispheric mode will lead to (a) vivid and free-flowing sensory imagery, and possibly to (b) out-of-body and other so-called 'anomalous' experiences.

(3) Defence mechanisms operate to protect the stability of attitudes and beliefs based in the D hemisphere. ND hemispheric learning will (a) bypass various defensive blocks to the acquisition of new knowledge and skills (e.g. the belief that one cannot learn them), and (b) in another context, will make it possible to 'unfreeze' long-established attitudes and behaviour patterns.

(4) Enhanced ND activity, which can act upon suggestions that would be rejected by the logical processing of the D hemisphere, will facilitate healing by implementing the functioning of the autonomic nervous system and the immune system.

Additional hypotheses can also be derived from the lists of D and ND-controlled types of behaviour (see below). Last but not least, it may be possible to measure the relative activation of the hemispheres directly, rather than inferring them from behavioural consequences. An optimal test at this level of analysis calls for either sophisticated EEG brain mapping or brain scanning techniques, but less precise assessments are possible with ordinary EEG equipment.

Because of the previously noted problems with earlier neuropsychological theories of REST effects, it is difficult if not impossible to devise experiments in which hypotheses generated by one model can be cleanly pitted against those derived from DHA—i.e. critical tests allowing strong inference (Platt, 1964). The early formulations make no predictions about the great majority of phenomena posited by DHA theory, and data bearing upon the latter model have little if any relevance to the former. However, in considering our studies testing the DHA model, we shall mention hypotheses and results that pertain to the earlier, ARAS-focused explanations.

Relevant Findings

Data relevant to Budzynski's hypotheses are summarized below, with additional research bearing upon new hypotheses derived from the theory. Readers who are relatively unfamiliar with recent REST literature should bear in mind that two methods for inducing profound stimulus reduction are currently popular: Chamber REST, in which the subject lies on a bed in a dark, soundproof room for up to 24 h, with food, water, and a chemical toilet available in the chamber so that there is no need to leave it during the session; and flotation REST, during which the supine subject floats in a tank containing a skin-temperature solution of water and Epsom salts. The solution is sufficiently dense that the face and chest remain out of the water and breathing is normal. The tank is dark and soundproof; session durations are usually one or two hours (for further details, see Suedfeld, 1980; Suedfeld *et al.*, 1990).

Accessibility of unconscious processes

Even in the earliest days of sensory deprivation research, experimenters and theorists talked about the production of 'regression in the service of the ego', the emergence of primary process, during the experience. Goldberger and Holt (1961), speculating about sensory deprivation tolerance, proposed that subjects who reacted negatively to REST were those who could not relax and enjoy the uncontrollable flow of normally unconscious material through their aware mind. A number of studies have found changes that the authors interpreted as showing regression (e.g. in chamber REST, Azima *et al.*, 1961; in flotation, Miller & Barabasz, 1990); but for the most part, the arguments are based on anecdotal reports and theory-driven interpretations that do not adequately consider alternative explanations. In contrast, a controlled study of autobiographical memory (Suedfeld & Eich, unpublished data),[4] round that the memories retrieved during REST had been more frequently retrieved before, and were also more pleasant, than those reported in a control environment. Neither repression nor trauma seems to figure in these aspects of free recall.

Imagery

Visual, auditory, and other imagery, including changes in body image, have been reported with great frequency by REST subjects. From a purely perceptual standpoint, the original emphasis on hallucinations as an effect of sensory deprivation seems to support the hypothesis of increased imagery (see, e.g. Reed, 1979). However, the findings were contaminated by definitional problems. Later research replaced the label 'hallucinations' by the less tendentious category, 'reported sensations' in various sensory modalities (e.g. 'reported visual sensations'). Although there are many such reports in REST, there is doubt about whether they occur more frequently than in other conditions where the subject concentrates on particular percepts. It is also unclear to what extent such experiences reflect such different phenomena as illusions, hallucinations, functional hallucinations, or delusional percepts; hypnagogic, hypnopompic, or eidetic imagery; spontaneous retinal firing, tinnitus, afterimages, or misperceptions; dreams, daydreams, fantasies; or residual stimulation transmitted through the walls, ceiling, or floor of the REST facility (Zuckerman, 1969*b*; Reed, 1979). These definitional problems may underlie contradictory reports as to, for example, brain activity related to the occurrence of reported sensations (Zuckerman & Hopkins, 1966; Rossi, 1967; Hayashi *et al.*, 1992). Experimenter expectancy and subject set also play a role (Jackson & Pollard, 1962; Zuckerman, 1969*c*).

Systematic research on cognitive imagery has not reported consistent increases as a result of REST. For example, although most flotation REST subjects in one experiment reported spontaneous, task-related, multimodal imagery (Barabasz *et al.*, 1993), a study of free-flowing thought during chamber REST found no increases in the quantity, content, or vividness of imagery or fantasy (Suedfeld *et al.*, 1985–86). Most thoughts dealt with real events happening in the subject's current daily life.

Experiment 1 tested another hypothesis about holistic imagery combining perception and cognition: the accurate recognition of incomplete figures by 'filling in' the missing parts through completion of a good Gestalt.

Experiment 1. The Effect of REST on Perceptual Closure

The major dependent variable in this study was perceptual closure: perceiving a holistic Gestalt in a figure that is presented in separated fragments. Perceptual closure has been linked with ND, synthesizing functions (Warrington & James, 1969; Harshman *et al.*, 1974; Crawford, 1979; Larsson, 1987; Levine & Calvino, 1989), and previous research has indicated that meditation increases both

ND hemispheric activity (Rubenzer, 1979) and perceptual closure (Larsson, 1987). Therefore, if REST enhances ND activity, it should also improve the perceptual closure of incomplete figures. This is a possible outcome of REST that would not be predicted by any of the other neuropsychological theories.

Twenty right-handed undergraduate volunteers (10 men and 10 women) with normal, or corrected to normal, vision spent one hour each in a dark, sound-reducing flotation tank (Experimental Environment) or sitting in a normally illuminated room where they were allowed to read, study, listen to music, or do anything else except leave (Comparison Environment). To measure perceptual closure, we used the Fragmented Figures Test (FFT; Snodgrass & Corwin, 1988), which presents the subject with a series of illustrations containing gaps in various locations. The subject's task is to identify what the picture shows (Figure 1 presents a relatively easy FFT-type stimulus). The FFT was administered the day before the environmental session and again immediately after completing either the float or the comparison experience (for more details of the flotation environment and procedure, see, e.g. Suedfeld *et al.*, 1987).

Secondary measures included the Absorption Scale (Tellegen & Atkinson, 1974) to assess whether floating increased this correlate of hypnotic susceptibility. Previous studies had indicated that chamber REST increases hypnotizability, but the evidence concerning flotation has been mixed (Wickramasekera, 1977; Barabasz, 1982; Kaplan & Barabasz, 1989). The last measure was the Telic Dominance Scale (Apter, 1982, 1989). In the telic state, people are goal-oriented, cautious, realistic, and arousal-avoidant; in the paratelic state, they are playful, spontaneous, imaginative, and arousal-seeking. We hypothesized that, in accordance with reversal theory (Apter, 1989), and compatibly with the DHA hypothesis, an hour of flotation would move subjects toward the paratelic state. The Absorption Scale was administered before the FFT on the pre-session day, and the Telic Dominance Scale just before the environmental manipulation. Both measures were re-administered after the session and the post-session FFT task.

Table 1 presents the FFT results. There was no significant baseline difference between the groups. Both groups improved from the pre- to the post-test ($F_{1,18} = 8{\cdot}95$; $p < 0{\cdot}01$). However, there was no significant main or interaction effect involving the REST experience.

There were no significant changes in either absorption or telic dominance. Thus, neither the perceptual nor the arousal/mood measures showed the predicted consequences of a shift toward ND activity; the evidence does not favour the DHA hypothesis.[5]

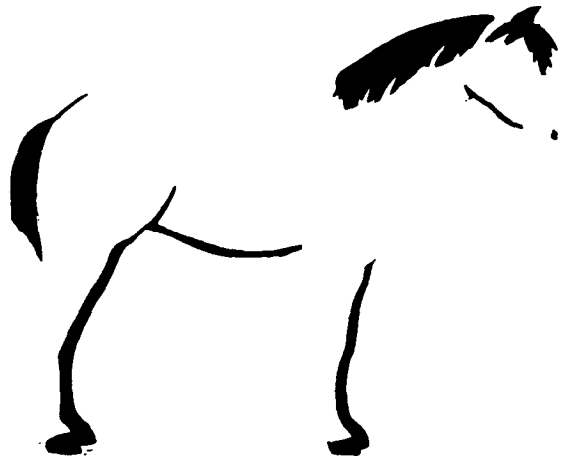

FIGURE 1. FFT-type stimulus (Experiment 1).

'Anomalous' experiences

As in the case of imagery, REST produces many anecdotes of out-of-body experiences, and a few self-reports of events that the subject interprets as involving parapsychological experiences. Again, the possibility that dreams or daydreams are interpreted in this way exists; on the whole, however, the anecdotal data support the hypothesis. No other kinds of data are available. REST does not appear to produce any great number of phenomena such as the 'sensed presence' experience, frequently found in situations of extreme stress and there attributed to the workings of the ND hemisphere (Suedfeld & Mocellin, 1987).

In summary, then, the data concerning imagery provide only partial evidence supporting the DHA model: 'perceptions without an object'—i.e. sensations without a verifiable external stimulus—are

TABLE 1
Correct solutions of FFT (Experiment 1)

Condition	Correct solutions	
	Mean	S.D.
REST		
Pre-test	14·5	2·95
Post-test	18·2	4·89
Comparison		
Pre-test	17·5	4·93
Post-test	19·1	5·22

common, but issues of definition and expectancy have not been settled; imagery in thought has been reported, but not confirmed experimentally; and complex, holistic imagery has not been well established.

Learning

The evidence supports the hypothesis that Budzynski derived from DHA theory. Dozens of experiments have presented verbal and visual material and have found that, on the whole, learning is enhanced by REST (Suedfeld, 1969*b*; Suedfeld & Landon, 1970). Most of this research has been conducted in the chamber version of REST, but Francis and Stanley (1985) reported enhanced memory for word lists, and Raab and Gruzelier (1992) for faces, after floating.

There is overwhelming evidence that new ways of behaving are greatly facilitated by REST. Such changes include the abandonment of persistent, long-established, but undesired habits such as smoking, excessive drinking, and overeating (Borrie & Suedfeld, 1980; Cooper *et al.*, 1988; Suedfeld, 1990*b*; P. Suedfeld & R. A. Borrie, unpublished data). New personality patterns—for example, in how one interacts with other people—also emerge after REST (Suedfeld & Best, 1977; Roy, 1991). Although change-enhancing messages sometimes help, the evidence indicates that both behavioral changes of this sort and changes in attitudes can be the consequences of REST with no other manipulation involved (Suedfeld & Ikard, 1974; Tetlock & Suedfeld, 1976). These findings fully support the DHA hypothesis.

Healing

There is evidence that REST aids healing in a number of contexts. Lee and Hewitt (1987) found that floating reduced recovery time from injuries among gymnasts; a number of groups have reported its usefulness as an adjunct to stress management and its beneficial effects on the secretion of stress hormones; both tank and chamber REST have been shown to decrease blood pressure, and so on (see Suedfeld *et al.*, 1990). One problem here is to establish the clear demarcation between the effects of REST as an arousal reducer and a form of deep relaxation from its possible effects on hemispheric dominance. We would need evidence about kinds of healing, for which the latter kind of change is a prerequisite, before we could conclude that the DHA explanation is the correct one.

Additional Hypotheses

Other behavioral effects that, hypothetically, may result from enhanced ND control, are as follows:

Cognitive style

The holistic, flexible 'right-brain' mode should be associated with improved originality and creativity (Rubenzer, 1979). Again, other neuropsychological theories of REST have no implications as to this phenomenon. Two types of research have been conducted on this issue, one using experimental tests of cognitive functioning and one looking at ecologically valid indices of creativity.

Divergent and complex thinking. Early studies on the effects of REST on divergent thinking had mixed results. For example, chamber REST enhanced solution times of the Duncker candle problem (Suedfeld et al., 1967), however, performance on associational fluency, on tasks of divergent thinking such as the Unusual Uses Test, and on *ad hoc* measures of original or complex thinking (inventing stories that incorporated unusual combinations of elements) show either impairment or no change as a function of REST (e.g. Suedfeld, 1968; Fuerst & Zubek, 1968; Zuckerman, 1969c; Oleson & Zubek, 1970; Landon & Suedfeld, 1977; Suedfeld *et al.*, 1983). All of these studies used the REST chamber; Experiment 2 was designed to explore the effect of flotation REST.

Experiment 2. Story-telling

Story-telling is a complex and unstructured task, with no obvious correct procedures or right answers, with an infinite number of possible choices of words and stories, and with no clear endpoint. As such, it should benefit from any change that enhances nonlinear, creative functions. Thus, improved performance (more complex integration of story elements, greater creativity) would be predicted as a result of REST by the DHA model. The other neuropsychological formulations would predict a decrease in performance because of the impaired level of concentration that is hypothesized to result from a disruption and deactivation of normal ARAS firing patterns.

Volunteer university students were randomly assigned to a two-hour flotation REST (n = 9) or Comparison (n = 10) environment. In the latter, subjects remained alone in a normally furnished

and illuminated room, where they could read, study, listen to the radio, etc. Three days before (baseline) and immediately after the session, each subject was instructed to tell a story based on one of two scenarios (order counterbalanced across administrations). Each scenario described one person performing an act, another attempting to gain the person's attention in a possibly antagonistic context, and a third person watching them both. The subjects were instructed to tell as detailed and dramatic a story as possible, including past, present and future events and also the thoughts and emotions of each character. The scenario for the second story-telling task was described immediately before task performance to prevent rehearsal during the REST or Comparison session.

As in the chamber REST studies cited above (Suedfeld, 1968), the primary measure of story complexity was the degree to which all three characters were integrated in each story (see Baker-Brown *et al.*, 1992). The stories were scored by trained assistants, who were blind as to the condition in which the story had been generated. To assess the degree of complete detailed explanations, as requested in the instructions, we also measured story length (word count). Other indices applied to the stories included speech rate, mean numbers of letters and syllables per word, and reading difficulty level (McLaughlin, 1969). There were no significant baseline differences on any of these measures.

Only two significant differences were found. One was that speech rate went down from baseline to the end of the experimental session, regardless of environmental condition, M = 113 vs 102 words per minute, $F_{1,17}$ = 6·31, p = 0·02. The other was an interaction showing that the complexity of the first component of each story (the explanation of what was going on in the scene) differed as a function of administration and environment. For REST subjects, complexity went up from baseline to post-session, M = 1·7 vs 2·8; for Comparison subjects, it went down, M = 2·9 vs 2·4, $F_{1,17}$ = 5·05, $p < 0·05$. Incidentally, story lengths after two hours of flotation REST were shorter than those generated after 24 hours of chamber REST (Suedfeld *et al.* 1964): just under 1000 words as compared to 1300. Similarly, flotation resulted in lower speech rate than chamber REST, 102 words per minute after flotation compared to 178 (Suedfeld *et al.*, 1964), possibly a concomitant of the well-known relaxing effect of floating.

The change in speech rate has no apparent relation to the DHA hypothesis, although it is compatible with the general relaxation and arousal-reduction predicted by both Budzynski (1976) and the other neuropsychological models. The significant complexity interaction supports the hypothesis in that subjects showed increased holistic integration after REST. However, because this change pertained only to the very first story component in each administration, any decrease in hemispheric asymmetry appears to be evanescent.

Creativity. One may argue that performance on experimental tests of divergent or integrative thinking may not be a valid index of activity. There have been two applications with somewhat higher ecological validity. Both reported that REST improved students' conceptual synthesis and scientific thinking about topics related to their educational programmes (physical and general chemistry, respectively: Shore, 1971; Taylor, 1990). In an experimental test of scientific creativity (new ideas concerning psychological research and theory), REST did lead to better ideas generated after floating than sitting in one's office (Suedfeld *et al.*, 1987).

Thus, although the number of controlled studies is small, the balance of the evidence concerning the effects of REST on creativity supports the DHA model.

Hand dominance

Normally, the hand contralateral to the D hemisphere—i.e. the dominant hand—is more effective than the other. Raab and Gruzelier (1992) have reported an interaction effect on sorting tactile stimuli, with the non-dominant hand improving after flotation and the dominant hand improving in a control condition. We conducted another study, with a task that is less cognitive and more purely motor-based than sorting, for a more easily interpreted test of the hypothesis (Lomas & Kimura, 1976).

Experiment 3. The Effects of REST on Finger-tapping Speed

In finger-tapping exercises, the speed of tapping with fingers of the dominant hand is considerably greater than that of the non-dominant hand (Barnsley & Rabinovitch, 1970; Piazza, 1977; Peters & Durding, 1978). This difference is apparently due to the dominant hand's more precise force modulation (Peters, 1980). Finger-tapping requires minimal disruption of REST conditions: it can be performed without extensive large-muscle movement, social

contact, or verbal interaction, and in relative dark and quiet. It is a straightforward motor task rather than one having, for example, major perceptual-cognitive components. Decreased asymmetry of activity between the D and ND hemispheres should be reflected in decreased asymmetry of finger-tapping speed between the dominant and non-dominant hands. ARAS-based theories would predict a general decease in activation level, and therefore a slowing of tapping speed regardless of which hand is being used.

Twenty-five volunteers of both sexes, most of whom were University students, were administered the Sensory-Motor Co-ordination Survey (Coren & Porac, 1978; Coren *et al.*, 1979), whose handedness items have a 96% concordance with behavioural tests. Three of the five left-handed subjects were assigned to the REST group (see below). Because there is no evidence to suggest that handedness mediates reactions to REST, and left- and right-handed persons show the same asymmetry in fingertap performance (Flowers, 1975; Annett, 1985), there should be no problem in using both as subjects.

Immediately prior to the environmental session, subjects were instructed to tap as rapidly as possible on a Morse-type telegraph key for 30 s; after a five-second pause, the task was repeated with the other hand. The order of hands (dominant/non-dominant) was counterbalanced. The task was administered again immediately after the session. Both administrations took place in the dimly lit room in which the flotation tank is located. REST consisted of a one-hour float; the Comparison condition was to remain on campus and return to the laboratory exactly one hour after the pre-test. The procedure was repeated exactly for each subject no less than 24 h and no more than 48 h after the first session, to test for effects of repeated floating. Because many subjects were disappointed to discover that another group had floated whereas they had not, Comparison environment subjects were then offered a one-hour float if they desired it.

ANOVA of the finger-tap scores showed a significant main effect for hand dominance, dominant hand M = 183·7 taps per minute, nondominant hand M = 168·3, $F_{1,18}$ = 42·5, p = 0·001. The pattern was the same regardless of the subject's handedness, and there was no baseline difference between the REST and Comparison group subjects. There was no significant difference between the two days in either environmental condition, and the data were therefore combined to yield pre- and post-test tapping speed scores.

Because the critical issue in this study was whether hand asymmetry changed as a function of the REST vs Comparison environment, the major dependent measure of asymmetry percentage was devised to equate for the individual differences in gross tapping speed. The measure provides a ratio, with the difference between the two hands as the numerator and overall tapping performance as the denominator: $[(D - ND)/(D + ND)] \times 100$. Higher scores on this measure indicate greater asymmetry between the performance of the two hands. There was a significant interaction between test administration and environmental condition, $F_{1,16}$ = 4·71, $p < 0·05$. Figure 2 shows the mean changes in asymmetry.

The data on hand dominance consistently disconfirm the ARAS-based predictions and support the DHA model to the extent that inferences concerning brain lateralization can be drawn from these results. It is interesting that when (as in Raab & Gruzelier, 1992) the task involved cognitive decision-making components, the reduced asymmetry between the two hands resulted from improved performance with the ND hand; on our own test of simple motor speed, the change in asymmetry was the result of a deterioration in the performance of the D hand. This difference in the pattern underlying the decrease in hand asymmetry seems worthy of further investigation.

Brain activity

Direct measurement of the activity levels of the two cortical hemispheres would, of course, be the most

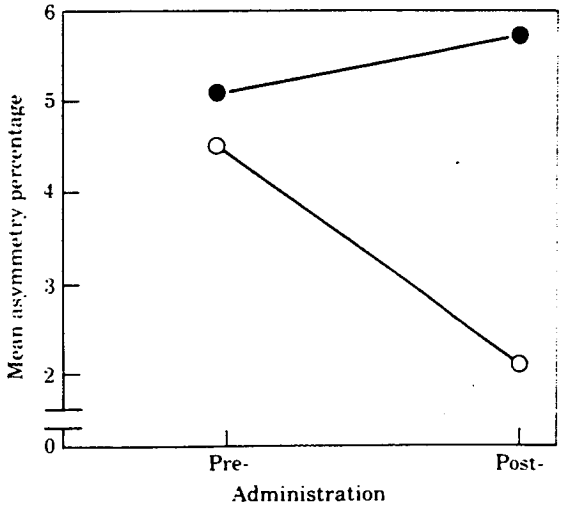

FIGURE 2. Pattern of hemispheric asymmetry during a one-hour flotation session. Experiment 3: asymmetry percentage = (D − ND)/(D + ND) × 100. (○), Rest; (●), Comparison.

direct way to assess the validity of the DHA hypothesis. The study reported below is the only attempt so far to conduct such an assessment.

Experiment 4. Bilateral EEG Patterns during REST

The DHA model predicts that with time in REST, activity in the ND hemisphere should increase relative to that in the D hemisphere. As before, competing neuropsychological models would predict a general decrease (slowing) in EEG activity across both hemispheres.

Ten male subjects (ages 25–40 years), of whom four had previous floating experience, volunteered in response to information circulated on campus. The electrode sites were P3, P4, F3, and F4. Measures of impedance were taken after electrode attachment, and all sites had to show an impedance of 5 K ohms or less.

While in the tank, each subject wore a latex rubber hood that covered the entire head and neck except for the face. This hood seals out the saline solution and prevents any short-circuit of the electrodes. It does not interfere with the subjective qualities of the REST experience. The EEG leads were attached to a watertight FM transmitter that transfers the signal to our telemetric recording apparatus, and EEG was continuously recorded on videotape during the one-hour float.

The signal, divided into left and right hemispheres, was integrated and digitized; the integrated signal was than ipsatized to cancel between-subjects effects. Each subject's signal was averaged over five 12-min periods. A 2 (hemisphere) × 5 (time block) repeated measures ANOVA yielded no significant main nor interaction effects. Ratio of activity of the two hemispheres, analysed by repeated measures ANOVA, showed no significant time effect. As Figure 3 shows, levels of symmetry remained unchanged from the first 12 min after the subject entered the tank until the end of the one-hour session. Thus, if REST did have the effect predicted by the DHA model, it would have had to achieve it within the first few minutes. We find this an improbable proposition. The results supported neither the DHA nor the other neuropsychological models of REST.

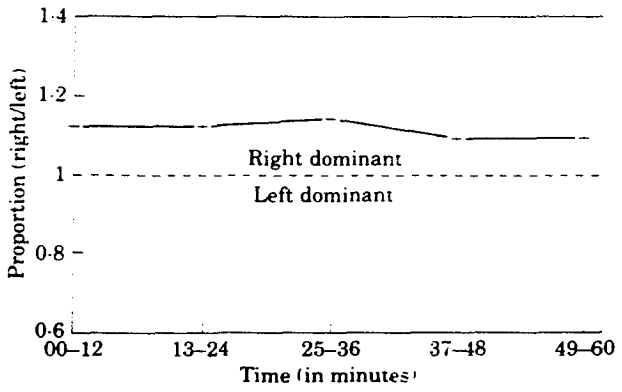

FIGURE 3. Ratio of hemispheric EEG activity (Experiment 4).

A technologically more sophisticated test, but without the use of a REST environment, was conducted by Mazziotta *et al.*, (1982). Using positron emission tomography (PET), these authors compared cerebral glucose mechanism in healthy subjects who had their eyes patched closed, their ears closed with rubber plugs and covered with soundproof headphones, or both. The measurement took place in a dimly lit room, with low ambient noise and restricted movement. While this condition is not really equivalent to REST, the eye-patched and ear-plugged subjects did experience a greater degree of stimulus reduction than those in other treatment conditions.

Left–right hemispheric symmetry characterized the entire group of subjects; but within that pattern, subjects who experienced both visual and auditory restriction showed a relative decrease in right-side metabolism—the opposite of what the DHA hypothesis would suggest. This same group also showed the greatest prominence of frontal lobe over occipital metabolism, which may suggest some new hypotheses.

Discussion

To date, results relevant to the DHA hypothesis of reduced hemispheric asymmetry as a consequence of REST have been mixed. Supportive data came from phenomenological reports of imagery, from one experiment that assessed creative behaviour, and from two tests of hand lateralization. The hypothesis has also been confirmed by sizable data bases showing increased attitudinal and behavioural flexibility, improved learning, and enhanced healing and stress reduction. In contrast, systematic studies of free recall and ongoing thought have been either inconsistent with the hypothesis or at least not clear-cut in their implications. Analyses of perceptual imagery generated negative evidence; and two direct measures of changes in brain functioning have not supported the hypothesis.

It appears that so far the results and their interpretation are not conclusive either in support of or in opposition to the DHA hypothesis. The status of

the DHA model at this point is not encouraging, especially given the greater significance of disconfirmation than of confirmation (Popper, 1961). One inference may be that either the time is not ripe for, or the effects of REST are not conducive to, neuropsychological theories and that other levels of conceptualization—such as, cognitive, affective, hormonal, or psychoanalytic—may be more fruitful. Nevertheless, DHA is one of the most testable general explanations of REST effects currently being considered. In addition to its potential as a generator of future research, the hypothesis may also be useful to scientists who are not interested in REST *per se*. The DHA theory aligns REST with other situations in which hemispheric asymmetry is thought to be temporarily modified: for example, meditation (Meissner & Pirot, 1983), hypnosis (Frumkin *et al.*, 1978), and REM sleep (Goldstein *et al.*, 1972; Gordon *et al.*, 1982). Requiring no practice or effort, achieving rapid results with most subjects, and leaving the subject awake and alert (although relaxed), REST may turn out to be a convenient and effective method of studying the elicitation of cerebral changes and their effects.

Such usefulness, of course, depends upon the fate of the DHA hypothesis after further empirical clarification. Perhaps it is unreasonable to expect early consensus in a body of evidence using so many different methods and looking at so many different dependent variables; nevertheless, it is to be hoped that the multimethod approach will set an example for theory-testing in this field. REST is itself a multimodal intervention, and has been shown to affect a wide range of psychological and psychophysiological variables (see, e.g. Zubek, 1969*a*; Suedfeld, 1980; Suedfeld *et al.*, 1990). It seems likely that an understanding of why it has those effects may require a theory that can be assessed only through research of comparable complexity. Until then, many schools of thought will no doubt continue to contend.

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Notes

(1) Address correspondence to: Professor P. Suedfeld Department of Psychology, the University of British Columbia, 2136 West Mall, Vancouver, B.C. Canada V6T 1Z4.

(2) Much of the early research on hemispheric specialization was conducted with split-brain patients. It might be interesting to see what the effects of REST would be on such participants—for example, whether decreases in D and increases in ND activity occur even when connections between the two have been severed. No such research has been performed to date.

(3) Another aspect of hemispheric independence, not mentioned by the three theories summarized here, may also be relevant to REST. Levy and Heller (1983) have suggested that ND arousal level is related to positive mood. Given the great preponderance of flotation REST studies that show decreases in negative and increases in positive affect during flotation, it would be interesting to test whether such a mood change mediates the REST-hemispheric dominance relationship (O'Leary & Heilbronner, 1985).

(4) Suedfeld, P. & Eich, E. (1992) *Autobiographical memory and affect under conditions of reduced environmental stimulation.* Unpublished MS, University of British Columbia.

(5) Vernon (1963) reports an experiment, designed to measure 'suggestibility' as a function of chamber REST, in which subjects were shown and asked to reproduce a series of geometrical figures. All of the figures were fully closed except the circles, the first presentation of which was closed while later examples had increasingly large gaps. The hypothesis was that suggestible subjects would fail to perceive the gaps until these were relatively large, which might also be predicted from a DHA, perceptual closure, or Gestalt perspective. Instead, Vernon found that REST subjects not only detected and accurately drew the gaps in the circles, they began to draw the other figures with gaps as well!

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