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Learning During Sleep

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Index

INTRODUCTION 1

SLEEP LEARNING: METHODOLOGY AND PHENOMENOLOGY 4
  Sleep Factors 4
    EEG Activation During and Following Item Presentation 4
    Sleep Specific Memory 8
  Item Factors 13
    Methods of Item Presentation 13
    Characteristics of the Target Items 14
  Task Factors 18
    Recall v. Recognition 18
    Memory for Events Experienced During Sleep: Remembering With and Without Awareness 19
  Subject Factors 24
    Age 24
    Health 25
    Capacity to Learn While Awake 26
    Suggestibility: Hypnotic Susceptibility and Learning Set 29

DISCUSSION 35

REFERENCES 37

INTRODUCTION

Is it possible for people to register and retain what is said in their presence while they sleep? If it is possible, is the learning that takes place during sleep efficient enough to be of practical as well as theoretical significance? These are the questions of chief concern in this paper. To address these issues, research dealing with a number of variables that may have an important influence on sleep learning is summarized in the second section of the paper, while in the third section, some tentative conclusions concerning the possibility and practicality of learning during sleep are offered, and prospects for future research are outlined. Much of the material covered in both of these sections has been culled from a remarkably thorough and trenchant review of the sleep learning literature by Aarons (1976), which I recommend to interested readers in the strongest possible terms.

As will become apparent in the course of subsequent discussion, solid facts about sleep learning are scarce, and only one of the variables to be considered--the level of electroencephalographic (EEG) activation that accompanies or follows the presentation of a to-be-learned or target item--has to date been examined in an empirically exacting manner. Although the present dearth of reliable data is unfortunate, it is also understandable. For many years following publication of the carefully controlled EEG experiments by Emmons and Simon (1956; Simon & Emmons 1956), sleep learning was a dead issue. They demonstrated that verbal information presented during sleep was irretrievable upon awakening unless presentation coincided with alpha activity, an EEG indicator of arousal or wakefulness. Their negative results, in combination with a highly critical commentary (Simon & Emmons 1955) on the positive results that had been obtained by others (e.g., Fox & Robbins 1952; Leuba & Bateman 1952), caused most researchers in the United States and other Western nations to abandon the idea that people may be able to learn while they sleep.

In more recent times, however, there has been a modest revival of interest in the possibility of sleep learning, owing to three important developments. First, a number of studies have shown that during slow wave (alpha free) sleep, subjects are able to make complex discriminations between repetitive auditory signals (e.g., Oswald et al. 1960), and to perform, when cued with appropriate sensory stimuli, motor responses which they had learned while awake (e.g., Okuma et al. 1966). One implication of these and related results (see Koulack & Goodenough 1976; Lehmann & Koukkou 1974) is that even during deep sleep, short-term storage of new information is possible, as is access to old information in long-term memory. Second, evidence from several sources (see Firth 1973; Goodenough 1978) suggests that habituation or conditioning of various physiological responses, such as heart rate and GSR, can occur during sleep, albeit at a slower rate than occurs during wakefulness. Since both habituation and conditioning represent forms of learning, this evidence implies that the inability to remember information presented during sleep may be attributable not to difficulties in storing the information, but rather, to a failure to retrieve the information on waking (Koukkou & Lehmann 1983; Koulack & Goodenough 1976). Third, there have been numerous reports out of the Soviet Union and other Eastern countries of success in demonstrating sleep learning (see Hoskovec 1966; Rubin 1968, 1971). Though there can be no doubt that learning is dramatically impaired during sleep (see Goodenough 1978; Oltman et al. 1977), these reports recommend a reappraisal of the conslusion that sleep learning is impossible, and raise a number of interesting questions concerning the conditions under which learning may occur. It is to these conditions that I now turn.

SLEEP LEARNING: METHODOLOGY AND PHENOMENOLOGY

As Aarons (1976) has observed, whether or not learning during sleep occurs depends on an intricate interplay of numerous psychological and physiological variables. In this section, I survey a selective sample of such variables--ones that, in my opinion, have the most promise of being important moderators of sleep learning. For ease of exposition, the specific variables to be considered are classified according to four general types: sleep, item, task, and subject.

SLEEP FACTORS

EEG Activation During and Following Item Presentation

The research of Simon and Emmons revealed that alpha activity during the presentation of a target item was a necessary condition for the later recollection of that item. Evidence also exists which suggests a strong association between memory performance and the both the level and duration of EEG wakefulness or activation patterns that follow item input. Evidence of this sort has been supplied by a number of studies (e.g., Jus & Jus 1972; Koukkou & Lehmann 1968; Lehmann & Koukkou 1974; Oltman et al. 1977), one of which is described below for purposes of illustration.

In the study by Koukkou and Lehmann (1968), short sentences were auditorily presented to subjects during slow wave (stage 2 or 3) sleep, and the duration of the EEG activation (alpha) pattern produced by the presentation of each sentence was measured. Upon awakening, the subjects completed a test of nominally noncued or “spontaneous” recall, which was succeeded by a test of old/new sentence-recognition memory.

The results showed that the duration of EEG activation that followed the presentation of a given sentence was quite short (mean = 9 sec) for sentences that were neither recalled nor recognized, significantly longer (mean = 26 sec) for sentences that were recognized but not recalled, and longer still (mean = 165 sec) for sentences that were spontaneously recalled verbatim (Koukkou & Lehmann 1968/Table IIB). These data clearly demonstrate that post-sleep recollection of sentences presented during slow wave sleep was related to the duration of EEG activation that occurred after presentation. (In later work, Lehmann and Koukkou (1974) demonstrated an analogous correlation between memory performance and the level (i.e., EEG wave frequency) of post-presentation activation.) The fact that intermediate durations of activation were associated with successful recognition, but unsuccessful recall, suggests that recognition may be a more sensitive measure of memory for sleep-presented material than is spontaneous recall--a point to which I will return later.

In an effort to provide a theoretical rationale for their results, Koukkou and Lehmann (1968) proposed that the duration (and level: see Lehmann &

Koukkou 1974) of EEG activation that occurs after the presentation of a target item reflects the time available for the long-term storage of that item. This proposal is reminiscent of the consolidation interpretation of sleep-learning problems put forth by Hebb (1949). According to Hebb's theory, there are two distinct forms of memorial representation: a short-term store in the form of reverberating neural circuits, and a long-term store involving the development of more permanent neural "knobs." It is the transformation or consolidation of information from a short- to a long-term representation that is assumed to be the process that is vulnerable to the absence of EEG activation.

Several observations are compatible with the consolidation account (see Goodenough 1978; Lehmann & Koukkou 1974). For example, somnambulists can can carry out complex motor actions and respond appropriately to sensory input during very deep (stage 4) sleep, but cannot recall their actions and responses once they awaken (Jacobson et al. 1965); the apparent accuracy of dream recall is high if sleepers are awakened during stage 1 periods of rapid eye movement (REM) sleep--a stage characterized by a fairly active EEG--but without sleep interruption, dream recall decreases with increased time spent in slow wave sleep after the end of the REM period (Dement & Kleitman 1957); and a number presented during deep sleep that is not followed by appreciable EEG activation can be recalled if the subject is intentionally and rapidly awakened before the short-term trace of the digit ceases to exist (Oltman et al. 1977).

Although much of the difficulty in recalling events that take place during sleep may reflect the impaired consolidation or long-term storage of these events, the possibility that recall difficulties may be due to deficient retrieval should not be overlooked. Within the last twenty years, several retrieval-based accounts of sleep-learning problems have been advanced (see Foulkes 1966; Goodenough 1978). One of the more recent of these--the functional state-shift hypothesis of Lehmann and Koukkou (1983)--is framed around the concept of dissociative or state specific memory: the idea that what has been learned in a particular state of mind or brain is best remembered in that state (see Eich 1977, 1980; Overton 1973, 1982). According to Lehmann and Koukkou (1983), the forgetting of events that transpire during sleep (whether internally generated dreams or externally presented items) is a function of the magnitude of the difference between the functional (EEG defined) states in which storage and retrieval of the events take place. Their hypothesis accords well with a number of diverse findings, one of which is the aforementioned fact that if a transient period of wakefulness (as indicated by an increase in EEG activation) occurs soon after the presentation of a target item, then the subsequent recall of that item will be possible during full wakefulness. In addition, the state-shift hypothesis carries the intriguing implication that information acquired during sleep may be accessible for retrieval in later occasions of sleep, though not during intervening periods of wakefulness. Evidence pertinent to this implication will be examined shortly. But first, I would like to make one other point concerning the correlation between EEG activation and memory performance.

As noted earlier, a number of Soviet and East European studies have reported success in producing relibale, sometimes robust, sleep learning effects. In these studies, presentations of the to-be-learned material are not regulated according to particular EEG patterns (as is customary in Western studies), but are timed to correspond with sleep onset, initial sleep, and early morning sleep--optimal times for eliciting EEG activations with alpha waves (Aarons 1976). Thus, it is entirely possible, even probable, that participants in these studies are not “really asleep” when presentation occurs, but instead are in a rather drowzy--but nonetheless conscious--state. Is it any wonder, then, that so-called sleep learning is possible under such circumstances? The obvious answer, of course, is “no,” but there is more to the story than that. Unlike their Western counterparts, Eastern researchers generally do not find the question, “Are subjects ‘really asleep’ during presentation of the learning material ?” to be an important or meaningful one to ask. Their primary concern is not with the theoretical possibility of learning during deep sleep, but rather, with the practical purpose it serves to present learning material to superficially sleeping subjects. This is one of several salient differences (others will be discussed in due course) that distinguishes the prototypical Western study of sleep learning from the prototypical Eastern study. As Aarons (1976) has argued, these differences probably account for why Western researchers frequently fail to find evidence of sleep learning, while Eastern investigators often succeed.

Sleep Specific Memory

In 1910, Morton Prince conjectured that the reason many people have difficulty remembering their dreams is not that they do not want to remember--as Freud (1900/1953) and other psychodynamically oriented theorists of the day were claiming--but rather, that they cannot remember, due to the mismatch between the states of natural sleep and ordinary wakefulness. Intuitively, Prince's speculation seems plausible, and so does Lehmann and Koukkou's (1983) idea that failures of waking memory for experimentally devised materials (such as sentences) that had been presented during sleep are attributable to the shift from sleeping to waking states. Plausibility is one thing, however; proof quite another. What empirical evidence is there to support the proposition that memory for events occurring during sleep is specific to the sleep state?

To my knowledge, only one study--described briefly by Evans et al. (1966), and more elaborately by Evans (1972) and Evans et al. (1969, 1970)--has sought to secure such evidence.

In this study, 18 student nurses slept in a laboratory for two or three nights. During the first night, suggestions of the form “Whenever I say the word ‘itch,’ your nose will feel itchy until you scratch it,” were auditorily presented to subjects while they were in alpha-free stage 1 sleep. The suggestions were then tested immediately by saying a cue word (“itch,” for instance) and observing the subjects' behavioral response, if any. Of the 18 subjects tested, 11 were able to perform the suggested responses while remaining in stage 1 sleep.

After the subjects awakened, they did not remember the verbally presented suggestions, nor did they remember responding to them. In addition, when presented with the same cue words that had elicited an appropriate response during sleep, the subjects did not respond behaviorally when awake. Thus the subjects appeared to have a dense waking amnesia for events that had occurred during the prior night's sleep.

That the absence of waking memory reflected amnesia rather than forgetting is implied by the observation that, of the 11 subjects who had responded to cue words during the first night, 7 responded to the same cues during the second night. Thus, in the majority of cases, successful second-night responding to cue words during sleep occurred even though the suggestions themselves were not readministered, and even though the subjects had no intervening waking recollection of the suggestions or their responses during sleep.

After an interval of approximately five months, seven subjects were retested on a third sleep night. None of these subjects remembered the events of either earlier evening, and five of the seven had responded on both prior nights to the cue words of the initial night. These five subjects responded, while in stage 1 sleep, to cue words from the first night's sleep, even though the suggestions had not been readministered and could not be consciously recalled in the intervening months.

To summarize, the results of Evans' study suggest that at least some subjects can respond to suggestions for specific motor actions while they remain in stage 1 sleep. Further, these responses can be elicited during stage 1 sleep of a following night, and even in the same sleep stage several months later, without further reinstatement of the suggestion. This retention occurs even though the subjects, when awake, are unable to either verbalize their sleep experiences or perform the sleep-acquired responses.

As I mentioned earlier, Evans' experiment is the only one of which I am aware that directly examined whether memory for events experienced during sleep is specific to the sleep state. Accordingly, his results, though strongly suggestive of sleep specific memory, should be viewed with caution. Why no efforts have evidently yet been made to replicate and extend Evans' findings is, to me, a mystery.

There is one other aspect of the relationship between state specificity and sleep learning that deserves attention, and it concerns the asymmetric form in which dissociative or state specific effects frequently appear. In several studies involving alcohol or other depressant drugs (e.g., Goodwin et al. 1969), it has been shown that although events encoded in an intoxicated state are “dissociated” or difficult to retrieve under conditions of sobriety, events experienced in the drug-free state are not state specific, and can be accessed as efficiently in the presence of alcohol as in its absence. An analogous pattern of results has obtained in research involving stimulant drugs, such as nicotine (Peters & McGee 1982), as well as in experiments entailing alterations of affect or mood. Bartlett and Santrock (1979), for example, found that if preschoolers learned a list of common words while they were feeling especially happy, they remembered many more of these words when tested for recall in a happy than in a neutral mood. However, words studied in a neutral affective state were equally well recalled regardless of whether the children were tested in a neutral as opposed to a happy mood. The implication of these and other studies (see Eich 1986) is that information “transfers” more completely from an ordinary or typical state of mind or brain (such as sobriety or neutral affect) to an atypical or altered state (such as alcohol intoxication or extreme happiness) than is does in the reverse direction. The main point I wish to make now is that asymmetrical dissociation may also be implicated in sleep. That is to say, while it is evident that knowledge acquired during wakefulness is expressable during sleep (we do, after all, tend to dream about things we perceived while awake), events experienced during sleep are difficult, if not impossible, to access during wakefulness. Why asymmetric dissociation should occur in conjunction with sleep, or any other experiential state (such as intoxication or happiness) for that matter, is an open issue. One possible reason relates to the concept of cue overload: the idea that the effectiveness of a given retrieval cue is inversely related to the number of discrete events it subserves (Watkins 1979; also see Bartlett et al. 1982; Eich 1985). Since the vast majority of our perceptual experiences occur while we are awake, the state of wakefulness cannot act as an effective cue for the retrieval of these experiences--it is simply too overloaded. Sleep, in contrast, may constitute a much more salient or distinctive context for encoding, and thus may serve as a powerful cue for the retrieval of events that had been encoded in the sleep state. It remains to be seen whether this reasoning can be developed into a satisfying account of asymmetric dissociation as it appears in concert with sleep or other experiential states.

ITEM FACTORS

Methods of Item Presentation

Although analyses of dream reports indicate that sleep mentation can be reliably and systematically modified by the external presentation of either visual or tactual stimuli (Arkin & Antrobus 1978), it is principally through audition that sleepers maintain contact with the external environment (Aarons 1976). For this reason, and in the interests of practicality, audition has been the sensory channel of choice in all studies of sleep learning reported to date.

Two methods of transmitting auditory information are available to the sleep-learning researcher: air conduction (loud speaker; e.g., Lehmann & Koukkou 1974; Simon & Emmons 1956) and bone conduction (pillow speaker; e.g., Bruce et al. 1970; Zukhar’ et al. 1965/1968). Although the former method has been used more often in past research, there is reason to think that the latter may be more conducive to the demonstration of sleep-learning effects. As Aarons (1976) has noted, bone transmits mainly in the low frequency range of speech, which includes the fundamental frequency of the speaker’s voice, and may therefore enhance the fidelity of the spoken message. Moreover, bone conduction has the curious effect of shifting the phenomenal source of speech from the outside to the inside of one’s head. That this may be beneficial for sleep learning is suggested by the idea (Foulkes 1966) that the extent to which external stimuli are ignored during sleep is reciprocally related to the sleepers' preoccupation with their own internal mentation. Thus, it is possible that sleepers may be more receptive to, and hence more retentive of, information that seems to originate in their own minds than in the outside world. Whether this possibility is real or remote is a matter that merits, but has not yet received, serious consideration.

Characteristics of the Target Items

The list of variables that have a significant impact on the learing of verbal items in the waking state is extremely long, and includes such factors as the frequency and spacing of item presentations, as well as the meaningfulness and familiarity of the items themselves (see Adams 1980; Baddeley 1976). Unfortunately, and almost unbelievably, the effect that these and other variables have on the efficiency of verbal learning during sleep is virtually unknown.

As regards the frequency of item presentation, Simon and Emmons (1955) asserted that sleep learning, if it is to occur at all, may require that a massive number of item presentations take place, but they did not offer any clean empirical evidence to back their claim. Bliznitchenko (1968; also cited in Aarons 1976), a pioneer in applied Soviet research on sleep learning, argued that repeated item presentations in the same sequence is a prerequisite to improvements in learning during sleep, but he too supplied no solid supporting data.

With respect to the spacing of item presentations, an early experiment by

Coyne, which is described in detail by Simon and Emmons (1955), indicated that distributed repetitions of the to-be-learned material (number-word pairs) produced superior sleep learning than did massed repetitions. However, Coyne's results are hopelessly confounded by the fact that the distributed repetitions occurred during the period just preceding wakefulness--typically a light, drowsy state--while the massed repetitions occurred during deeper and possibly less receptive stages of sleep.(see Simon & Emmons 1955).

The conflicting results revealed by several studies involving nonsense syllables, common words, simple sentences, and even Chinese-English paired associates prompted Simon and Emmons (1955) to conclude that meaningfulness is not a critical determinant of sleep learning. However, as Aarons (1976) has noted, no sleep learning studies have yet been reported in which the semantic or denotative dimensions of the learning material is subject to systematic manipulation. Aarons has also remarked that apart from whatever role semantic meaningfulness may play in sleep learning, the personal meaningfulness or affective significance of the learning material may be important. In this regard, it is interesting to note that hand movements and electrographic (K complex) responses occur more frequently when subjects are presented, during deep sleep, with their own than with someone else's name (Oswald et al. 1960), and that emotionally toned words, in contrast to neutral items (e.g., dumb, sin v. drum, sit), provoke more pronounced eye movements and cardiovascular changes when presented during sleep than during wakefulness (Minard et al. 1968). Given that personally or affectively meaningful material is more apt to be registered during sleep, it would be most interesting to know whether such material is also more likely to be retained upon awakening.

Earler I pointed out that a salient difference between Western and Eastern studies of sleep learning is that in the former, material is presented only during EEG-defined sleep, whereas in the latter, presentation occurs at the beginning and end of the normal sleep cycle. Another significant difference concerns the learner's familiarity with the material. In most Western studies, subjects do not know what it is they will hear while they sleep, and they usually participate in only a single sleep-learning session. In contrast, Eastern investigators have developed a “hypnopaedic tutorial system” (see Rubin 1970) in which the presentation of material during superficial sleep is coordinated with ongoing audiovisual presleep and postsleep instruction that lasts for several weeks. Although it has been claimed that this system accelerates the learning of telegraphy, foreign-language vocabulary, and other types of practical knowledge (see Aarons 1976; Bliznitchenko 1968; Rubin 1971), the absence of appropriate controls makes it impossible to determine how much of the learning is attributable to waking instruction alone. Still, the possibility exists that the presentation of learning material during sleep improves performance in the waking state--provided that the material is familiar to the learners prior to its presentation.

Preliminary support for this possibility has been provided by Tilley (1979). Subjects in his experiment examined a set of 20 pictures of single objects (culled from a children's picture book) at bedtime. Later that night, a tape-recorded list of 10 words--the names of half of the pictures in the original set--was presented 10 times during either Stage 2 or REM sleep. The following morning, the subjects were tested for free recall and recognition of the 9complete set of 20 picture names.

In comparison with items that had been studied at bedtime only, those that had been presented both before and during sleep were significantly better recalled and recognized. Curiously, the beneficial effect of repetition during sleep was much more evident in the morning retention of items that had been repeated during Stage 2 sleep than those that had been repeated during REM. This finding is curious in that REM, which is characterized by low-amplitude EEG activity and the periodic appearance of alpha frequencies, would seem to be more conducive to the processing of incoming information than would non-REM (in this case, Stage 2) sleep. Be that as it may, Tilley's results are clearly consistent with the Soviet claim that pre-sleep learning can be strengthened or reinforced through within-sleep repetition. It is equally clear, however, that Tilley's results need to be replicated, and if possible, extended to other types of learning materials and retention tasks.

TASK FACTORS

Recall v. Recognition

Although a few studies have used savings in relearning to assess the retention of sleep presented materials--often with contradictory outcomes: compare, for instance, the positive results obtained by Fox and Robbins (1952) with the negative findings of Bruce et al. (1970)--most have employed tests of recall, recognition, or both (see Aarons 1976/Table 2).

There is some reason to think that recognition may be a more sensitive measure of memory for events experienced during sleep than is recall. As noted earlier, Koukkou and Lehmann (1968; also see Lehmann & Koukkou 1974) found that items whose presentation during slow wave sleep was followed by an intermediate duaration and level of EEG activation could subsequently be recognized, though not spontaneously recalled. Also, Levy et al. (1972) observed that although subjects were unable to recall Russian-English paired associates that had been presented during either stage 1 or stage 4 sleep, recognition of the response or target words was slightly but significantly above chance for both sleep stages. And a recent study by Johnson et al. (1984) showed that the probability of recalling a dream that had been immediately reported upon awakening fell to below .20 after a two-week retention interval, while the probability of recognizing the dream was an impressive .80 after the same interval.

Why events experienced during sleep should be more readily recognized than recalled remains to be determined. It is of some interest to note, however, that basic memory research involving more conventional materials suggests that how readily information is comprehended and organized may matter more for recall than for recognition (see Kintsch 1970). Conceivably, then, events that occur during sleep may be particularly difficult to recall either because sleep is not conducive to the coherent organization of ongoing events, or because the events themselves are incomprehensible (as often appears to be the case for dreams).

Memory for Events Experienced During Sleep: Remembering With and Without Awareness

Evidence from several soruces suggests that memory for past events can influence present actions even if one is not aware of remembering the earlier experiences. As an example, prior presentation of a word makes it more likely that college students can report that word, when later it is briefly exposed in a perceptual identification task, regardless of whether or not they recognize the word as one that had been presented before (Jacoby & Dallas 1981). Similarly, amnesic patients reveal effects of practice in their subsequent performance of a cognitive, perceptual, or motor skill, even though they cannot remember ever having practiced that skill (Schacter & Tulving 1982). These are related observations imply that it is possible to distinguish the effects of memory for prior episodes or experiences on a person's current behavior from the person's awareness that he or she is remembering events of the past (Eich 1984;

Jacoby 1982; Moscovitch 1982; Tulving et al. 1982).

The point I wish to make here is that it may be useful to apply the distinction between memory and awareness of memory to the question of whether events that occur during sleep can be registered and retained. As noted above, most earlier experiments examining this question have focused on the an individual's ability to recall or recognize a specific item--a spoken number, word, or sentence, for example--as having occurred in a specific situation--namely, while the individual was superficially or soundly asleep. Memory as measured in these experiments is deliberate or intentional, in that the person must necessarily be aware that he or she is remembering a particular past event (Jacoby & Dallas 1981; Jacoby & Witherspoon 1982). Since most people appear profoundly amnesic when tested for the deliberate recall or recognition of events to which they had been exposed while asleep, it may be condifently concluded that events that are denied conscious attention are ordinarily not amenable to conscious reflection, or accessible through "aware" forms of remembering. The conclusion need not be drawn, however, that events occurring during sleep leave no lasting impression in memory and exert no enduring effect on behavior. The possibility exists that even though the effects of memory for sleep-experienced events may not--and probably cannot--be revealed in tests of retention that require remembering to be deliberate or intentional, such effects might become manifest in tests that do not demand awareness of remembering.

How might this possibility be empirically explored? One straightforward way of doing so is suggested by a recent study by Jacoby and Witherspoon (1982). Participants in this study were five university students and five Korsakoff alcoholics, clinically diagnosed as amnesic. In the first phase of the study, the subjects were asked to answer questions such as: "Name a musical instrument that employs a reed." As implied by this example, the intent of the question-answering task was to encourage the subjects to encode homophones, such as reed, in relation to their low-frequency or less common interpretations.

In the second phase of the study, the subjects were read a list that consisted in part, of equivalent numbers of old and new homophones--ones that either had or had not appeared in the context of biasing questions--and were asked to spell each word aloud. Jacoby and Witherspoon reasoned that if the first presentation of a "biased" homophone is remembered and influences its later interpretation, more of the old than the new homophones should be spelled in line with their less common interpretations. They further reasoned that an influence of memory on the spelling of a word would not necessarily require the subjects to be aware that they were remembering the first presentation of that word, but that such awareness would be required in the test of old/new recognition memory that was given in the third and final phase. To the extent, then, that memory and awareness of memory represent distinct, dissociable dimensions of human cognition, performance on a memory test (viz. recognition) that requires awareness of earlier events, and performance on a test (viz. spelling) that does not demand deliberate remembering should be independent of one another, in that performance on one type of test should not be predictable on the basis of performance on the other type.

Evidence of such independence was revealed in two ways. First, in comparison with the students, the amnesic patients recognized far fewer old homophones (25 v. 76%, with neither group of subjects generating any false positives), but spelled more of these items in line with their less common, experimentally biased interpretations (63 v. 49%, with approximately 21% of the new homophones spelled in their low-frequency forms by both groups). Thus the disadvantage of the amnesic patients was restricted to recognition memory--an “aware” form of remembering. Second, for patients and students alike, the conditional probability of recognizing an old homophone in the third phase of the study, given that its spelling had been biased by memory in the second phase (p(Rn/Sp)), did not differ significantly from the unconditional probability of corrent recognition (p (Rn)). Thus, for neither type of subject was recognition memory associated with or enhanced by an effect of memory on spelling.

In summary, it appears that the prior presentation of a word has a substantial impact on its subsequent interpretation and spelling, regardless of whether or not the word is correctly classified as “old” in a later test of recognition memory. Although this dissociation of spelling and recognition performance is especially striking among the amnesics (who outperformed the students on the former test, and were themselves outperformed by the students on the latter), it is demonstrated by the nonamnesics as well (as evidenced by the students’ statistically equivalent values of p(Rn/Sp) and p(Rn)). Recognition and spelling thus seem to reflect fundamentally different forms or functions of memory, whether intact or organically impaired. In particular, whereas recognition of an old word requires the recognizer to be aware of its prior presentation, an influence of memory on the spelling of a word does not necessarily demand deliberate remembering (see Eich 1984; Jacoby 1982).

Approached from the standpoint of sleep learning, the idea that recognition and spelling tap different memory processes or systems raises an interesting question for research. Specifically, suppose that during sleep, a person is presented with a series of short, descriptive phrases, each consisting of a homophone and one or two words that bias the homophone's less common interpretation (e.g., war and PEACE; deep SEA). Suppose further that, upon awakening, the subject is read a list composed chiefly of old and new homophones (ones that either had or had not been presented during sleep) on two successive occasions. On one occasion, the subject is simply asked to spell each list item aloud; on the other occasion, the subject is asked to state aloud which list items he or she recognizes as having been presented during sleep. Given the situation sketched above, might the subject spell significantly more old than new homophones in line with their less common interpretations, and yet fail to reliably discriminate between the two types of items in the test of recognition memory--a test, unlike that of spelling, which would presumably require the subject to consciously reflect upon events that had occurred during a state of unconsciousness? More broadly stated, is it possible that people know something about events that take place during sleep, but not know that they know? The answer to this question might be of interest from an applied as well as a theoretical perspective.

SUBJECT FACTORS

Age

Several authors have speculated about whether the ability to learn during sleep is dependent upon age, but no one has to date provided any telling data. Svyadoshch (1962/1968), for example, employed subjects ranging in age from 10 to 60 years in a series of studies concerning the reproduction of stories presented during sleep. Although Svyadoshch asserted that the majority of his subjects--irrespective of their age--demonstrated a high level of text reproduction (arbitrarily defined as 66% of more of the story material), he did not provide a breakdown of reproduction scores by age group. Svyadoshch also offered no hard numbers to support a second assertion concerning the relationship between sleep learning and age--one that is seemingly at odds with the first: specifically, that the ability to assimilate speech during sleep can be acquired “artificially” by means of suggestions delivered in the context of either deep hypnosis or ordinary wakefullness, and that children and adolescents, being more suggestible by nature than older adults, are especially adept at developing sleep-learning abilities.

Interestingly, the idea that an optimal period for learning how to learn during sleep may arise at an early age has also occurred to Aarons (1976), but for different, and more defensible, reasons. These include the observation that (a) even as early as three days after birth, the human voice and its fundamental frequency are more effective than other sounds in eliciting behavioral and physiological reactions during alert, relaxed, and somnolent states (Hutt et al. 1968), (b) children appear to acquire second languages more readily than do adults, which suggests a greater facility in phonetic processsing during wakefulness that could conceivably carry over to sleep, and (c) in comparison with older children, younger children devote more attention to and are more likely to remember auditorily rather than visually presented information (Hallahan et al. 1974). Although the foregoing observations are compatible with the developmental hypothesis advanced by Aarons (1976), more direct evidence is clearly needed. Obtaining such evidence would doubtless be a difficult and demanding task, but potentially a rewarding one as well.

Health

Given that (a) between five and ten percent of otherwise healthy medical students suffer from chronic sleep disturbances that range from mild to moderate in severity (Johns et al. 1971), (b) emotional stress disrupts the natural sleep cycles of men and women alike (Breger et al. 1971), and (c) both mentation and physiological processes during sleep are influenced by menstruation in women (Sheldrake & Cormack 1974), the need to screen subjects for sleep-learning research on the basis of specific criteria related to their physical and psychological health seems clear. Yet apart from the research of Zukhar' and his associates (1965/1968), in which people with histories of sleep disturbance were specifically excluded from participation, health-related variables have not been taken into account in prior studies of sleep learning. Instead, researchers have simply assumed that their subjects are in generally good health and have normal hearing. As Aarons (1976) has remarked, information on personal health and sleep habits would aid investigators in determining the suitability of a particular person to a particular sleep-learning intervention, and it is therefore hoped that the gathering of such information will become a standard practice in future studies of sleep learning.

Capacity to Learn While Awake

According to Simon and Emmons (1955), sleep-learning researchers would be well advised to select as their subjects people who are particularly proficient at learning in the waking state, since the effects of presenting material during sleep may be so subtle that its benefits will be evident only in highly intelligent individuals. In consideration of Simon and Emmon's conjecture, four points are worth making. First, there is no a priori reason to assume that general intelligence plays a more prominent role in learning during sleep that it does in wake instruction (Aarons 1976). Second, it seems plausible to think that positive effects of sleep learning might be more readily demonstrated in individuals who are deficient rather than proficient in wake-state acquisition, in much the same manner as the memory-enhancing effects of nootropic drugs, such as oxiracetam (Itil et al. 1982), may be more likely to obtain in memory impaired patients (e.g., those with senile dementia of the Alzheimer's type) than in cognitively intact controls. Third, there is no empirical evidence to support Simon and Emmon's position, and fourth, what little evidence does exist--and it is indeed little, as I will emphasize momentarily--runs counter to Simon and Emmon's conjecture. The pertinent evidence comes from an early experiment by Elliott (1947/1968). All 40 of the subjects in Elliott's study first learned one list of words (List A) to criterion in the waking state. Subsequently, a second list (B) was presented to 20 subjects while they slept (the experimental group), but not to the other 20 (the control group). The following morning, all 40 subjects learned List B to criterion. The key finding was that the percentage of savings in learning list B (i.e., $S_B = (N_A - N_B/N_A) \times 100$, where N_A and N_B designate the number of trials required by a given subject to learn Lists A and B) was significantly greater for experimental than for control subjects--a finding that Elliott interpreted as evidence of sleep learning. For present purposes, a more interesting finding concerns the correlation between the values of N_A and S_B for each group of subjects. For purely statistical reasons, one would expect to observe a positive correlation between these measures for either group (since if any two subjects take the same number of trials to learn List B, the one who required more trials to learn List A will necessarily obtain a higher savings score). However, if Simon and Emmon's speculation that the benefits of sleep learning are more likely to be detected in good than in poor wake-state learners, then one would also expect to find a smaller correlation between the N_A and S_B scores of experimental subjects than between those of control subjects. That is to say, good learners in the experimental group (those who required relatively few trials to master List A) ought to show more savings in their learning of List B than should poor learners in the same group (those who required relatively many trials to learn List A). In fact, the correlation between N_A and S_B is somewhat greater among the experimental subjects (` = +.37) than it is among the control subjects (` = +.21). (These correlations were calculated from the data presented in Table III of Elliott (1968, p 13).) Thus, the advantage of having been presented with List B during sleep on later learning of that list appears to have accrued more to the poor than to the good wake-state learners in Elliott's study--the opposite of what would have been anticipated on the basis of Simon and Emmon's account. I emphasize the word "appears" because Elliott's experiment was not free of methodological flaws (for one thing, he did not continuously monitor sleep using EEG; see Simon and Emmons (1955)). More rigorous research will need to be performed before the relationship between learning capacities in waking and sleeping states can be stated with any degree of precision.

Suggestibility: Hypnotic Susceptibility and Learning Set

According to several Soviet accounts (e.g., Svyadoshch 1962/1968; Zavalova et al. 1964/1968; also see Aarons 1976; Hoskovec 1966), learning during sleep is possible provided that the learners are suggestible. As a rule, however, Russian researchers have not been either clear or consistent in their usage of the term “suggestible”--at times the term appears to imply susceptibility to hypnosis, at other times it refers to a strong waking set that is induced in the subjects to convince them that sleep learning is a bona fide phenomenon, and on still other occasions the term connotes both of these senses--and the evidence they have presented to support their position cannot be regarded as compelling.

Consider, for example, the work of Kulikov (1964/1968). Subjects in his studies numbered 21 grade school and 15 college students, all of whom were highly susceptible to hypnosis (as tested by the method of hand gripping). The subjects were (randomly?) separated into three groups of 12, each composed of 7 children and 5 adults.

Subjects in the first group were repeatedly presented during natural sleep with a narrative (a Tolstoy story for the children; a description of nervous system functions for the adults), and were tested for recall of the text when they awoke. These subjects were not, as Kulikov put it, “prepared” for sleep learning; that is, they had received no specific suggestions for assimilation and retention of the text prior to its presentation. Kulikov did not specify the number of times the text was presented, the precise form of the recall test (i.e., whether it was spontaneous or prompted), or the duration of the retention interval. Further, it is not clear from Kulikov's account exactly when the text was presented; the only procedural remarks he makes in this regard is that the text was presented, via tape recorder, at a volume that was below the threshold of hearing in the waking state, and that sleep was monitored by taking activity records (absence of motor movements) and pneumographic tracings (absence of marked respiratory reaction). Be that as it may, Kulikov found that only one of the 12 subjects in this group had any waking recollection of the text, and the one exceptional subject was a boy who had taken part in previous studies in which hypnopedic suggestions had been delivered.

Testing of subjects in the second group started by establishing contact with them while they slept. After the subjects had been sleeping for one or two hours, tape-recorded suggestions were presented to the effect: "You are sleeping peacefully, do not wake up," and "your breathing is becoming deeper and deeper." Having made contact with the sleeping subjects in this manner, the suggestion was given: "Now you will hear a story, listen to what is said, try and memorize it as much as possible, you will remember this all your life, and whenever wanted you will be able to relate it." The text was then presented (an unspecified number of times), and was followed by additional suggestions to remember the text and to sleep soundly.

The impact these suggestions had on the subjects waking-recall performance appears to have been profound. Among the 12 subjects in the second group who had been "prepared" with a suggested set to learn while asleep, the percentage of idea units contained in the text that were recalled averaged 64%, and ranged from 47% to 87%; there was no appreciable difference in the performance of the children and the adults. These figures are remarkably similar to those yielded by the third group of subjects, who were awake at the time of text presentation (mean recall: 66%, range: 44% to 80%).

Taken at face value, Kulikov's data indicate that learning during sleep is possible in hypnotically suggestible subjects when a suggested set to register and retain the learning material is involved. Moreover, his data suggest that the capacity to learn during sleep is comparable to that of the waking state.

Kulikov's results are not beyond reproach, however. For one thing, the suggested set that was imparted to subjects in the second group was evidently not induced in subjects representing the third group, thus preculding a valid comparison of effectiveness of sleep v. wake learning. For another, it is possible that the striking difference in recall performance found between the first and second groups does not demonstrate the importance of preparing subjects for sleep learning, but rather reflects the fact that only the second group of subjects received any suggestions at all. A more meaningful contrast would have been between groups receiving suggestions that either were or were not relevant to the specific learning task at hand.

Although Kulivov's (1964/1968) studies have some serious shortcomings, his contention--one shared with other Soviet researchers (see Hoskovec 1966)--that sleep learning is possible in hypnotically susceptible subjects who have acquired an appropriate set to learn finds support in a small study by Evans (1972), an American-based investigator. Nine of the subjects in Evans' experiment were people of varying levels of hypnotic susceptibility, all of whom could respond, while remaining asleep, to suggestions for specific motor actions (e.g., "Whenever I say the word 'pillow,' your pillow will feel uncomfortable until you move it."), without a presleep "set" to perform these actions; none of the subjects had any waking recollection of these suggestions. A strong waking set was then instilled that sleep learning is possible. Specifically, the subjects were told that, unlike most people, they were able to respond to suggestions presented during sleep, and that this made them particularly promising canadidates for sleep learning. Further, the subjects were informed about successful Soviet demonstrations of sleep learning, and so the subjects were motivated both by their own special qualifications and by the competitive aim to duplicate the Russian results. In addition to these nine subjects, several others were included who did not receive the suggested set.

Material of the form "A is for Apple," "P is for Palace," was presented to the subjects during sleep stages REM, 2, and 4. Any letter-word pair whose presentation was accompanied simultaneously by alpha was excluded from subsequent analyses of retention. Eight target words, each beginning with a different letter, were presented twice to each subject; at least two different words were presented during each sleep stage.

Waking retention was tested by having the subjects check any familiar word on a list of 10 words beginning with "A," and again from 10 words beginning with "P," etc.; two similar "dummy" lists, containing words that had not been presented during sleep, were also administered. Thus, the conservative probability of recognizing a target word by guessing was .10 for each of the eight relevant lists.

Three main findings emerged from the recognition test. First, subjects who had not received the set to learn during sleep recognized none of the target words from any sleep stage. Second, subjects who had received the set recognized, on the average, .28, .10, and .00 of the words that had been presented during stages REM, 2, and 4, respectively; none of these subjects ever claimed to recognize a word that was not a true target. Thus, only those words that had been presented to "set" subjects during REM sleep were recognized at a better-than-chance level. Third, among the suggested-set subjects, those who had a relatively high level of hypnotic susceptibility (as indexed by the Stanford Hypnotic Susceptibility Scale, among other instruments) tended to recognize more stage REM targets than did subjects who had a relatively low level (`= .49).

Viewed as a whole, the results of Evans' (1972) experiment seem to square with the Soviet position that sleep learning is possible in hypnotically susceptible subjects in whom a strong set to learn has been established. As such, Evans' results illuminate a number of interesting issues for future research. By way of example, consider first the concept of suggested set. Intuitively, it seems reasonable to suppose that what the induction of a set does is increase the subjects' motivation to learn while they sleep. If motivation is indeed one of the keys to successful sleep learning, then the odds of observing significant sleep-learning effects should be improved by offering subjects a substantial monetary reward for good retention performance (e.g., Levy et al. 1972), by ensuring that the material to be learned during sleep is pertinent to the subjects' personal needs or educational goals (e.g., Balkhasov 1965/1968), or by restricting the subject sample to individuals who have a strong interest in the research (e.g., Svyadoshch 1962/1968).

Turning now to the role of hypnotic susceptibility in sleep learning, research reviewed by Hilgard (1979) indicates that high hypnotizables are able to process information outside of conscious awareness more effectively and completely than are low hypnotizables. A striking example of this “splitting” of consciousness, a process termed dissociation, is when a person discovers that he or she is reacting, in an apparently automatic or involuntary manner, to a suggestion implanted previously under hypnosis. Owing to their greater dissociative abilities, high hypnotizables may be able to selectively attend and process incoming information without consciousness awareness after they have fallen asleep. Lacking this ability, low hypnotizables have to awaken to process similar information, and are therefore incapable of learning while they sleep. Although this hypothesis is as speculative as it is sketchy, it does seem to fit with the findings that, in comparison with low hypnotizables, high hypnotizables are (a) less likely to awaken either spontaneously or following verbal stimulation (Evans 1972), (b) more likely to respond to behavioral suggestions administered during sleep (Evans et al. 1966, 1969), and (c) more adept at changing their dream experiences to conform with specific presleep instructions (Belicki & Bowers 1982). These findings, in addition to the others mentioned earlier in this section, suggest that the relations among hypnotizability, dissociability, and sleep learning represent an inviting target for future research.

DISCUSSION

Whether it is possible and practical for people to learn while they sleep is a question to which Western and Eastern researchers have given different answers. Little, if any, learning has been revealed in most Western studies, wherein novel verbal material is presented to unselected subjects during a single session of EEG-defined sleep. Whatever learning that has materialized in these studies has frequently been found to be correlated with both the duration and level of EEG wakefulness patterns that coincide with or closely follow presentation of the learning material. In contrast, evidence of substantial sleep learning has emerged in numerous Eastern studies, wherein familiar material is presented to "suggestible" subjects who have a strong presleep set to learn, and who are willing to participate in a lengthy training regimen. No attempt is made in these studies to input information during deep stages of sleep; instead, presentations are timed to correspond with sleep onset, initial sleep, and early morning sleep--periods in which significant EEG activations are likely to occur. Any improvements in performance obtained under these conditions would thus appear to reflect a compostite of wake and sleep experience, and not pure, unadulterated "sleep learning."

While it appears clear that information whose presentation, during sleep, is not accompanied by EEG activation is not retained unpon awakening, it would be most interesting to know, for theoretical as well as for applied reasons, whether there is any substance to to Soviet claim that substantial improvements in learning can be achieved by way of a systematic program of combined wake/sleep instruction. It would also be informative to discover whether such improvements are dependent upon the learners' age, their health, their capacity to acquire knowledge in the waking state, their susceptibility to hypnosis, and their motivation or set to learn; on the nature of the learning materials (e.g., whether they are affectively intoned or personally insignificant) and the methods of material presentation (e.g., air- v. bone-conducted transmission); and on the means by which memory for the material is measured (e.g., whether the test of retention administered does or does not require awareness of remembering). These are among the many issues that remain to be settled in future research aimed at investigating both the possibility and the practicality of learning during sleep.

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Accelerated Learning

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Over the past fifteen years there have been extraordinary gains made in our understanding of the elements that constitute effective instruction. One important source of information has been research on teaching, which has studied the behaviors characteristic of teachers whose students make outstanding learning gains (see, for example, Brophy & Good, 1986; Rosenshine & Stevens, 1986). Another has been fundamental advances in psychology of learning (e.g., Anderson, Spiro, & Montagne, 1977). A third source of new information and perspectives has been experimental research on such instructional methods as mastery learning (Bloom, 1976), cooperative learning (Slavin, 1983a, b), computer-assisted instruction (Kulik, Bangert, & Williams, 1983), and Suggestive Accelerative Learning Techniques (Schuster & Gritton, 1985).

This paper represents an effort to summarize the current status of research on effective instruction. It presents a model of effective instruction, discusses research on each of the elements of this model, and uses the model to discuss research on specific instructional techniques. The research discussed was almost all conducted in elementary and secondary schools, but the implications of the review for military training are examined at the end of the paper.

Elements of Effective Instruction

In recent years, research on teaching has made significant strides in identifying teaching behaviors associated with high student achievement (Brophy & Good, 1986; Rosenshine & Stevens, 1986). For example, research on the presentation of lessons has examined such issues as type and level of questionning (e.g., Winne, 1979; Redfield & Rousseau, 1981), lesson organi zation (e.g., Belgard, Rosenshine, & Gage, 1971), and transitions between ideas (e.g., Smith & Cotton, 1980).

However, effective instruction is not just good teaching. If it were, we could probably find the best lecturers, make video tapes of their lessons, and show them to students. Consider why the video teacher would be ineffective. First, the video teacher would have no idea what students already knew. A particular lesson might be too advanced for a particular group of students, or it may be that some students already know the material being taught. Some students may be learning the lesson quite well, while others are missing key concepts and falling behind because they lack prerequisite skills for new learning. The video teacher would have no way to know who needed additional help, and would have no way to provide it in any case. There would be no way to question students to find out if they were getting the main points and then to reteach any concepts students were failing to grasp.

Second, the video teacher would have no way to motivate students to pay attention to the lesson or to really try to learn it. If students were failing to pay attention, the video teacher would have no way to do anything about it. Finally, the video teacher would never know at the end of the lesson whether or not students actually learned the main concepts or skills.

The case of the video teacher illustrates the point that teachers must be concerned with many elements of instruction in addition to the lesson itself. Teachers must attend to ways of adapting instruction to students' levels of knowledge, motivating students to learn, managing student behavior, grouping students for instruction, and testing and evaluating students. These are elements of classroom organization that are at least as important as the quality of teachers' lessons.

A Model of School Learning

One of the most influential articles ever published in the field of educational psychology was a paper by John Carroll entitled "A Model of School Learning" (1963). In it, Carroll describes teaching in terms of the management of time, resources, and activities to ensure student learning. The model proposes five elements that contribute to the effectiveness of instruction: Aptitude, ability to understand instruction, perseverance, opportunity (time), and quality of instruction. Carroll discusses these elements in terms of time needed to learn and time available for learning. The higher are students' aptitudes, the better their abilities to understand instruction, and the greater their perseverance, the less time it will take to teach them a skill or concept. The higher the quality of instruction, the less time will be needed. On the other side of the balance sheet is opportunity; there must be adequate time to teach a lesson.

Carroll's model mixes two kinds of elements: Those that are directly under the control of the teacher, and those that are characteristics of students, which are difficult to change in the short run. Quality of instruction and opportunity (time) are directly under the control of the teacher or the school. Aptitude is mostly a characteristic of students over which teachers can have little control in the short run. Ability to understand instruction and perseverance are partly under the control of the teacher, but partly characteristic of students. For example, ability to understand instruction is partly a product of student ability, but is also a product of what teachers do to make sure that students have all the prerequisite skills and information they will need to successfully learn a new lesson. Persev erance results both from the motivation to learn that a student brings to school and from specific strategies a teacher or school might use to motivate students to do their best.

I have proposed elsewhere (Slavin, 1984; in press) a model of effective instruction which focuses on the alterable elements of Carroll's model, those which teachers and schools can directly change. The components of this model of alterable elements of effective instruction are as follows:

1. Quality of Instruction. The degree to which information or skills are presented so that students can easily learn them. Quality of instruction is largely a product of the quality of the curriculum and of the lesson presentation itself.
2. Appropriate Levels of Instruction: The degree to which the teacher makes sure that students are ready to learn a new lesson (that is, they have the necessary skills and knowledge to learn it) but have not already learned the lesson. In other words, the level of instruction is appropriate when a lesson is neither too difficult nor too easy for students.
3. Incentive: The degree to which the teacher makes sure that students are motivated to work on instructional tasks and to learn the material being presented.
4. Time: The degree to which students are given enough time to learn the material being taught.

The four elements of this QAIT (Quality, Appropriateness, Incentive, Time) model have one important characteristic: All four must be adequate for instruction to be effective. Again, effective instruction is not just good teaching. No matter how high the quality of instruction, students will not learn a lesson if they lack the necessary prior skills or information, if they lack the motivation, or if they lack the time they need to learn the lesson. On the other hand, if the quality of instruction is low, then it makes no difference how much students know, how motivated they are, or how much time they have. Each of the elements of the QAIT model is like a link in a chain, and the chain is only as strong as its weakest link.

Toward a Theory of Effective Classroom Organization

Most of the advances in recent research on teaching have come about as a result of correlational process-product research, in which the practices of instructionally effective teachers have been contrasted with those of less effective teachers, controlling for student inputs. In recent years, the findings of these process-product studies have been incorporated into coherent instructional programs and evaluated in field experiments. Other coherent instructional methods not based on the process-product findings, such as mastery learning, cooperative learning, and individualized instruction methods, have al so been evaluated in field experiments. Each of these instructional methods is based on its own psychological or educational theories. However, it is the purpose of this paper to propose a theory to encompass all potential forms of classroom organization. Given a relatively fixed set of resources, every innovation in classroom organization solves some problems but also creates new problems which must themselves be solved. Tradeoffs are always involved. Understanding the terms of these tradeoffs is critical for an understanding of how to build effective models of classroom organization.

The QAIT model proposed above is designed primarily to clarify the tradeoffs involved in alternative forms of classroom organization. This paper presents a perspective on what is known now about each of the QAIT elements, explores the theoretical and practical ramifications of the interdependence of these elements for the design of effective instructional methods, and applies the QAIT formulation to a discussion of effective models for classroom instruction.

Quality of Instruction

Quality of instruction refers to the activities we think of first when we think of teaching: Lecturing, discussing, calling on students, and so on. When instruction is high in quality, the information being presented makes sense to students, is interesting to them, is easy to remember and apply.

The most important aspect of instructional quality is the degree to which the lesson makes sense to students. For example, teachers must present information in an organized, orderly way (Belgard, Rosenshine, & Gage, 1971), note transitions to new topics (Smith & Cotton, 1980), use many vivid images and examples (Anderson & Hidde, 1971), and frequently restate essential principles (Maddox & Hoole, 1975). Lessons should be related to students' background knowledge, using such devices as advance organizers (Ausubel, 1960) or simply reminding students of previously learned material at relevant points in the lesson. Enthusiasm (Abrami, Leventhal, & Perry, 1982) and humor (Kaplan & Pascoe, 1977) can also contribute to quality of instruction.

Clear specification of lesson objectives to students (Dalis, 1970) and a substantial correlation between what is taught and what is assessed (Cooley & Leinhardt, 1980) contribute to instructional quality, as does frequent formal or informal assessment to see that students are mastering what is being taught (Dunkin & Biddle, 1974: Peckham & Roe, 1977) and immediate feedback to students on the correctness of their performances (Barringer & Gholson, 1979).

Instructional pace is partly an issue of quality of instruction and partly of appropriate levels of instruction. In general, content coverage is strongly related to student achievement (Dunkin, 1978; Barr & Dreeben, 1983), so a rapid pace of instruction may contribute to instructional quality. However, there is obviously such a thing as too rapid an instructional pace. Frequent assessment of student learning is critical for teachers to establish the most rapid instructional pace consistent with the preparedness and learning rate of all students.

Appropriate Levels of Instruction

Perhaps the most difficult problem of school and classroom organization is accommodating instruction to the needs of students with different levels of prior knowledge and different learning rates. If a teacher presents a lesson on equations in two variables to a heterogeneous class, some students may fail to learn it because they have not mastered such prerequisite skills as solving equations in one variable. At the same time, there may be some students who know how to solve two-variable equations before the lesson begins, or learn to do so very rapidly. If the teacher sets a pace of instruction appropriate to the needs of the students lacking prerequisite skills, then the rapid learners' time will be largely wasted. If the instructional pace is too rapid, the students lacking prerequisite skills will be left behind.

There are many common means of attempting to accomodate instruction to students' diverse needs, but each method has drawbacks that may make the method counterproductive. Various forms of ability grouping seek to reduce the heterogeneity of instructional groups. Between-class ability grouping plans, such as tracking, can create low-ability classes for which teachers have low expectations, maintain a slow pace of instruction, and dislike to teach (Good & Marshall, 1984; Rowan & Miracle, 1983; Slavin, 1986a). However, forms of ability grouping in which students are regrouped across grade lines and instructional level is based on performance level rather than age can be instructionally effective (Slavin, 1986a).

Mastery learning and individualized instruction are two widely used means of accommodating instruction to students' needs. These are discussed later in this paper.

Incentive

Thomas Edison once wrote that "genius is one percent inspiration and ninety-nine percent perspiration." The same could probably be said for learning. Learning is work. This is not to say that learning must be drudgery, but it is certainly the case that students must exert themselves to pay attention, to study, and to conscientiously perform the tasks assigned to them, and they must somehow be motivated to do these things. This motivation may come from the intrinsic interest value of the material being learned, or may be created through the use of extrinsic incentives, such as praise, grades, special privileges, and so on.

If students want to know something, they will be more likely to exert the necessary effort to learn it. This is why there are students who can rattle off the names, batting averages, and other statistics relating to every player on the Chicago Cubs, but do not know their multiplication facts. Teachers can create intrinsic interest in material to be taught by arousing student curiosity, for example by using surprising demonstrations, by relating topics to students' personal lives, or by allowing students to discover information for themselves (Gregory, 1975; Berlyne, 1965).

However, not every subject can be made intrinsically interesting to every student at all times. Most students need some sort of extrinsic incentive to exert an adequate level of effort. For example, studies of graded versus pass-fail college courses find substantially higher achievement in classes that give grades (Gold, Reilly, Silberman, & Lehr, 1971; Hales, Bain, & Rand, 1971). One critical principle of effective use of classroom incentives is that students should be held accountable for everything they do. For example, homework that is checked has been found to contribute more to student achievement than homework that is assigned but not checked (Austin, 1978). Also, questioning strategies that communicate high expectations for students, such as waiting for them to respond (Rowe, 1974) and following up with students who do not initially give full responses (Brophy & Evertson, 1974) have been found to be associated with high achievement.

Several methods of providing formal incentives for learning have been found to be instructionally effective. Among these are strategies based on behavioral learning theories which provide praise, tokens, or other rewards contingent on students' classroom behavior (O'Leary & O'Leary, 1972). One practical and effective method of rewarding students for appropriate, learning-oriented behavior is home-based reinforcement (Barth, 1979), provision of daily or weekly reports to parents on student behavior. Another is group contingencies (Litow & Pumroy, 1975; Hayes, 1976), in which the entire class or groups within the class are rewarded on the basis of the behavior of the entire group. Cooperative learning methods (Slavin, 1983a, b), which involve students working in small learning groups to master academic material, are instructionally effective forms of group contingencies discussed later in this paper. Rewarding students based on improvement over their own past performance has also been found to be an effective incentive system (Natriello, in press; Slavin, 1980).

In addition to being a product of specific strategies designed to increase student motivation, incentive is also influenced by quality of instruction and appropriate levels of instruction. Students will be more motivated to learn about a topic that is presented in an interesting way, that makes sense to them, and that they feel capable of learning. Further, students' motivations to exert maximum effort will be influenced by their perception of the difference between their probability of success if they do exert themselves and their probability of success if they do not (Atkinson & Birch, 1978; Slavin, 1977, 1986b). That is, if a student feels sure of success or, alternatively, of failure, regardless of his or her efforts, then incentive will be very low. This is likely to be the case if a lesson is presented at a level much too easy or too difficult for the student, respectively. Incentive is high when the level of instruction is appropriate for a student. If the student perceives that with effort the material can be mastered, the payoff for effort will be perceived to be great.

Time

Instruction takes time. More time spent teaching a subject does not always translate into additional learning, but if instructional quality, appropriateness of instruction, and incentives for learning are all high, then more time on instruction is likely to pay off in greater learning.

The amount of time available for learning depends largely on two factors: Allocated time and engaged time . Allocated time is the time scheduled by the teacher for a particular lesson or subject and then actually used for instructional activities. Allocated time is mostly under the direct control of the school and teacher. In contrast, engaged time, the time students actually engage in learning tasks, is not under the direct control of the school or teacher. Engaged time, or time-on-task, is largely a product of quality of instruction, student motivation, and allocated time. Thus, allocated time is an alterable element of instruction (like quality, appropriateness, and incentive), but engaged time is a mediating variable linking alterable variables with student achievement.

While allocated time must be an essential element in any model of classroom organization, research on this variable has found few consistent effects on student achievement. For example, research on hours in the school day and days in the school year has found few relationships between these time variables and student achievement (Frederick & Walberg, 1980; Karweit, 1976, 1981). The Beginning Teacher Evaluation Study found no effect of allocated time in specific subjects on student achievement in those subjects when time was measured at the class level (Marliave, Fisher, & Dishaw, 1978). On the other hand, research on engaged time generally finds positive relationships between of time students are on task and their achievement, but even with this variable results are inconsistent (see Karweit, 1981).

Studies of means of increasing student time on task generally go under the heading of classroom management research. Process-product studies (see, for example, Brophy, 1979) have established that teachers' use of effective management strategies is associated with high student achievement. Research on classroom management methods based on behavioral learning theory has established that such methods as token economies, group contingencies, and home-based reinforcement can increase student time-on-task and (in many cases) thereby increase student achievement (O'Leary & O'Leary, 1972).

A Model of Alterable Elements of Instruction and Student Achievement

As noted earlier, Carroll's (1963) model of school learning discusses five elements in terms of their effects on time needed to learn and time available to learning. The QAIT model, whose elements were described in the previous sections, can also be conceptualized in terms of intermediate effects on time-related variables. Figure 1 depicts a model of how alterable elements of instruction might affect student achievement.

Figure 1 Here

In Figure 1, two types of independent variables are presented: Student inputs and alterable variables. Student inputs refer to factors over which the school has little control in the short run: Student ability and those aspects of motivation to learn that students bring from home (as distinct from the motivation created by classroom practices). The alterable variables are the QAIT elements discussed earlier. Of course, student inputs are not immutable, but can be affected by classroom practices. For example, student aptitude to learn a specific lesson may be strongly influenced by background knowledge resulting from earlier instruction, by specific training in thinking, problem solving, or study skills, or by general intellectual stimulation or learning skills provided by the school. Student motivation to learn is also largely a product of past experiences in school. However, in the context of any given lesson, the student inputs can be considered fixed, while the alterable variables can be directly manipulated by the school or teacher.

The effects of the alterable variables on student achievement are held to be mediated by two time-related variables: Instructional efficiency and engaged time, or time-on-task. Instructional efficiency can be conceptualized as the amount of learning per unit time. For example, students will learn more in a ten-minute lesson high in instructional efficiency than in a lesson of similar length low in instructional efficiency. Engaged time is the amount of time students are actually participating in relevant learning activities, such as paying attention to lectures and doing assignments. Instructional efficiency is simply the inverse of Carroll's "time needed to learn," and engaged time is essentially his "time available for learning." Instructional efficiency and engaged time are multiplicatively related to student achievement; obviously, if either is zero, then learning is zero.

The QAIT model can be easily related to instructional efficiency and engaged time. Instructional efficiency is a product of the quality of instruction (e.g., organization and presentation quality of the lesson), appropriate levels of instruction (students have prerequisite skills but have not already learned the lesson), and incentive (students are interested in learning the lesson). These factors are multiplicative related to instructional efficiency, meaning that if any of them is zero, instructional efficiency and therefore achievement will also be zero. Of course, aptitude and motivation also contribute to instructional efficiency for any given student. Engaged time is primarily a product of allocated time and incentive.

The contention that the relationships between the alterable variables, instructional efficiency and engaged time, and student achievement are multiplicative is of critical importance to the model proposed here. In addition to implying that achievement will be zero if any of the alterable variables are zero, it also implies that while improving any one of the variables is likely to increase achievement arithmetically, improving more than one is likely to increase achievement geometrically. Since there are many random or uncontrolled factors in student achievement, and since achievement in any particular skill is so much a function of prior knowledge, ability, and motivation, it may be that for any new program to have a measurable effect on student mean achievement, it must improve multiple elements of instruction and therefore have a geometric effect on learning, particularly when a measure of general learning (such as a standardized test) is used as a criterion of success for a program implemented over a substantial period of time. For example, consider how much additional vocabulary students in an experimental program would have to learn to show a measurably greater gain than control students on a standardized reading vocabulary test not specifically keyed to the material students studied. The chance elements involved in determining whether words or decoding skills taught in the experimental program actually appeared on the vocabulary test would make it unlikely that any small effect of improved instruction would be detected.

EFFECTIVE INSTRUCTIONAL MODELS

The value of any theory or model lies in its usefulness in explaining or clarifying phenomena of interest. The remainder of this paper uses the concepts of the QAIT formulation to discuss research on several innovations directed at accelerating student achievement, and ends with a discussion of the application of these methods and of the QAIT model itself to military training.

Individualized Instruction.

Individualized or programmed instructional methods were developed primarily to solve the problem of differences in student prior knowledge and learning rate by allowing students to work on materials at their own levels and rates. In theory, individualized instruction should bring about a substantial improvement in the provision of appropriate levels of instruction. Yet reviews of research on the achievement effects of the individualzed models developed in the 1960's and '70's have uniformly concluded that these methods had few if any positive effects on student achievement (Hartley, 1977; Horak, 1981; Miller, 1976; Schoen, in press). The individualized methods were based on sound psychological theories and the materials were carefully constructed and piloted. What went wrong?

One possibility is that what individualized instruction gained in appropriate levels of instruction it then lost in quality of instruction, incentive, and time. One serious problem of individualized instruction is that it forces students to rely on printed material for the great majority of their instruction. If a teacher had enough aides to check student work, manage the flow of materials, and respond to non-instructional demands, and was extraordinarily well organized, the teacher could still spend only two minutes with each of twenty-five students in a fifty-minute period. In fact, many teachers using individualized programs spend most of their class time checking student work and managing materials, not teaching at all except when students have specific problems. The quality of instruction provided by the best written material is unlikely to match that provided by a teacher. Further, the incentive value of doing the same types of worksheets day after day with little interaction with other students or with the teacher cannot be very great for many students. Finally, the necessity for a substantial amount of time for procedural activities, such as waiting for materials to be checked, reduces time available for learning, and any lack of of incentive to make rapid progress may further reduce engaged time.

An individualized mathematics program designed to solve these problems of the 1960’s models provides an interesting point of contrast. This is Team Assisted Individualization, or TAI (Slavin, 1985), an individualized mathematics program for the upper elementary grades. In TAI, students work in four-member heterogeneous learning teams. Students work within their teams on programmed materials appropriate to their own level of preparedness, check one another’s work against answer sheets, help one another with problems, and take care of all management concerns. The teams are rewarded based on the progress of each team member thorough the individualized sequence of units. Since the students themselves take responsibility for all checking and routine management, the teacher is free to spend all period teaching groups of students drawn from the different teams who are perform ing at about the same level; students typically receive 10-20 minutes of direct instruction every class period. The team incentive, found in previous research to be a powerful motivator (Slavin, 1983a,b), provides ample motivation for students to proceed at a rapid rate with high accuracy and to help one another to master difficult concepts. This incentive may produce high levels of engagement, perhaps enough to counterbalance the time needed to engage in checking or management-related activities.

Research on TAI has clearly established that when direct instruction and team incentives are added to an individualized program, achievement is accelerated. In six field experiments evaluating the program, the mean grade equivalent gain in computations on standardized tests was twice as great for TAI classes as that for control groups (Slavin, Leavey, & Madden, 1984; Slavin, Madden, & Leavey, 1984; Slavin & Karweit, 1985; Slavin, 1985). A component analysis of TAI by Cavanaugh (1984) found that the team incentive system was important to the success of the program.

The contrast of the results of TAI to those of earlier individual models suggests that individualization is not inherently ineffective, but can be made effective if in addition to providing appropriate levels of instruction it also provides adequate direct instruction (quality of instruction) and enhanced incentives for learning. Attention to all four elements of effective instruction turned out in this case to be necessary to produce a positive effect on student achievement.

Computer Assisted Instruction

Computer Assisted Instruction, or CAI, refers to a wide range of means of using computers to help students learn, from drill-and-practice programs to tutorials to simulations and games. CAI offers a means of providing students with one-to-one, individualized instruction that, while very expensive, is much less expensive than providing live tutors. Also, there are many kinds of instruction (such as realistic simulations) that can only be provided by computers.

The effectiveness of CAI for enhancing student achievement depends on many factors. One is the type of learning objective. For objectives that lend themselves to simulation, computers are uniquely appropriate. An example of such an objective is flight training, where computerized flight simulators have been standard for decades. Another example of this sort of application is “in-box” exercises, where the student is learning to perform a job in which he or she must deal with incoming information in real time. Obviously, learning computer programming requires a computer.

For more traditional school learning, the benefits of CAI are less clear. Leaving aside simulations and computer programming, there are two major types of CAI used for instructional purposes. Drill-and-practice programs are by far the most common in elementary and secondary schools. These programs present students with problems, and the students type in their answers. The computer then indicates whether the answers were correct and often keeps track of the number of errors made. Tutorial programs vary their presentations of material according to student responses. For example, in many tutorial programs the computer will provide additional instruction or explanation before giving aditional problems of the same type, or will move the student rapidly if he or she is responding correctly.

Research on instructional uses of CAI indicates consistently positive effects only when CAI is used in addition to regular classroom instruction (Atkinson, 1984; Kulik, Bangert, & Williams, 1983; Chambers & Sprecher, 1983; Clark & Leonard, 1985). However, it is not clear whether it is the computer that is producing additional learning or if it is the additional time in itself. However, some studies (e.g., Ragosta, 1983) have found strong effects of CAI when it is used only ten to fifteen minutes per day (in addition to regular instruction). When CAI is used instead of regular classroom instruction, its effects on student achievement are much smaller and more inconsistent; in fact, when time, objectives, and instructors are all held constant, there is some question of whether there is any effect of CAI at all (Clark & Leonard, 1985).

It is interesting to note that despite the theoretical advantages of tutorial over drill-and-practice instruction, few differences have been found between them in their achievement effects (Kulik, Bangert, & Williams, 1983).

The problems of CAI are similar to those of programmed instruction, which it strongly resembles. CAI can substantially solve the problem of providing appropriate levels of instruction, but it may do so at a cost in instructional quality, as few computer programs can compare with the instruction provided by a talented teacher. CAI may increase motivation over the short run, but this wears off; studies showing the strongest positive effects of CAI have generally been quite brief, two weeks or shorter (Clark & Leonard, 1985). In terms of the QAIT model, CAI produces positive effects principally when the gains it provides in appropriate levels of instruction are accompanied by a gain in instructional time.

Mastery Learning

Mastery learning is one of the most widely used of all instructional innovations. The basic idea behind mastery learning is the principle that differences in student performance are due to differences in the time students need to learn. Mastery learning theorists (e.g., Bloom, 1976) hold that the normal distribution of scores students exhibit on any performance test arise from the practice of holding instructional time constant for all students and allowing learning to vary. They suggest that instead, learning should be held constant and time allowed to vary. To accomplish this, students in mastery learning are given clear objectives, such as achievement of a score of 90% on a test of the content studied. Students may require two or more attempts to pass this test. Those who fail to pass the test on the first try receive corrective instruction designed to remediate any learning problems. It is in this corrective instruction that time is varied for students; at least in theory, students receive as much corrective instruction as they need to master the test at the designated criterion.

Mastery learning is used in two primary forms. In group-based mastery learning (Block & Anderson, 1975), also called Learning for Mastery or LFM, students are taught in class groups. The teacher presents a one-to-four week lesson and then gives a formative test. Students who achieve a pre-established criterion (usually 80-90% correct) are given enrichment work or may serve as tutors to others. Students who fail to achieve the criterion receive corrective instruction from the teacher. This cycle may be repeated until nearly all students have achieved the criterion score. When mastery learning is used at the elementary or secondary levels, it is almost always one or another form of a group-based model.

In contrast, the second primary form of mastery learning, the Keller Plan (Keller, 1968) or Personalized System of Instruction (PSI), is used almost exclusively at the post-secondary level. In PSI, a set of tests are prepared to cover the content of a course and students may take as long as they need to pass them. Students may attend lectures, work with student tutors, or use self-instructional materials, but the responsibility to master the tests is essentially theirs.

Both forms of mastery learning deal primarily with providing appropriate levels of instruction. They approach the problem of student heterogeneity not by accommodating instruction to student performance levels (as in individualized instruction) but rather by varying instructional time to equalize student performance levels. In this way, students can learn from group instruction because they have all mastered the prerequisites, regardless of how long it took them to do so. Mastery learning theorists would also hold that incentive is also increased, particularly for low achievers who perceive a chance to succeed if they exert themselves.

Outcomes of group-based mastery learning in elementary and secondary schools have been mixed, but appear to depend on how these programs are organized (Slavin, forthcoming). The most common form of group-based mastery learning, which follows the teach-formative test-corrective instruction/enrichment-summative test cycle described above, has not generally been found to be superior to traditionally taught control groups in achievement of objectives taught equally in both treatments. For example, year-long experiments by Anderson, Scott, & Hutlock (1975), Kersh (1972), and Slavin &

Karweit (1984) found no significant advantage on standardized tests for mastery learning programs. However, in some studies instructional time was increased by providing corrective instruction outside of class. This increased total time for low achievers, who in some cases received as much corrective instruction as initial instruction (doubling their total instructional time), and avoided the problem of shunting high achievers aside to do enrichment activities. Studies of this type have found consistent achievement advantages for mastery learning as compared to traditional programs (e.g., Arlin & Webster, 1983; Dillashaw & Okey, 1983; Swanson & Denton, 1977; Wentling, 1973).

The research on group-based mastery learning may support the prediction of the QAIT model that attending only to appropriate levels of instruction is not enough to significantly increase student achievement, but when a second element is also increased (in this case time), achievement is increased. However, it may be that the increase in instructional time, not the mastery learning program, is what accounts for the positive effects in the extra-time studies. Obviously, students who receive twice as much instruction will learn more than other students. A critical assumption of mastery learning theory is that because students always have prerequisite skills for what they are to learn, the need for corrective instruction will diminish over time. However, long-term research (e.g., Arlin, 1984) questions this assumption.

Research on PSI (Keller Plan) is more consistently supportive of this approach (Kulik, Kulik, & Cohen, 1979). In general, students in PSI calsses achieve at a higher level than those in traditional classes. PSI students spend somewhat more time on their coursework than do other students, but probably not enough to account for the effects. However, PSI students perceive their courses as significantly harder and more time-consuming than do traditionally taught students, and perhaps for that reason withdrawal rates for PSI courses are higher than for other courses.

One problem in all mastery learning research is that by its nature mastery learning (whether group-based or PSI) focuses students and teachers on a narrowly defined set of objectives. When performance on those objectives is assessed, it is hardly surprising that mastery learning students achieve them better than other students. Even when mastery learning and control teachers agree on a common set of objectives and a common examination, it is likely that the mastery learning teachers will focus on those objectives more directly than will control teachers, who are much more likely to teach additional material that will not be on the test. In practice, this means that when there is a very specific set of objectives to be mastered and all students must master them, mastery learning approaches are particularly appropriate, but may be less appropriate when objectives are less concrete and variations in outcomes are acceptable. For example, mastery learning might be more appropriate in teaching the periodic table of the elements or automobile mechanics, which have limited, easily specified objectives, than in teaching the history of World War II or principles of evolution.

Peer Tutoring

Long ago, educators realized that students could help one another learn. For example, the Lancastrian System of the nineteenth century solved the problem of a shortage of teachers for children of the poor by having older students teach younger, less advanced students.

Peer tutoring usually involves older student tutoring younger ones (called “cross-age tutoring). One reason for this is that students often resent being tutored by a classmate. Research on cross-age tutoring has found consistent positive effects on the achievement of the student receiving tutoring (the “tutee”), and equally strong effects in many cases on the achievement of the tutor, who apparently learns a great deal from the tutoring experience (Devin-Sheehan, Feldman, & Allen, 1976; Cloward, 1967). Schools sometimes take advantage of this latter finding by using as tutors older students who are having difficulties with basic skills themselves. By having them tutor younger students, they must review the basic skills they failed to master earlier in a setting that gives them high status.

Effects of peer tutoring are particularly strong when tutors are trained in highly structured “programmed tutoring” methods (Ellson, 1976) which give tutors step-by-step procedures to follow in instructing and praising their tutees. As in the case of CAI and mastery learning, effects of peer tutoring are particularly strong when tutoring is done in addition to, not instead of, regular classroom instruction. However, peer tutoring does still appear to be quite effective when instructional time is held constant.

Peer tutoring is often used as part of other methods. For example, it is a routine component of the Personalized System of Instruction (PSI), or

Keller Plan, and is often used to provide corrective instruction in group-based mastery learning. Informal peer tutoring is central to cooperative learning, discussed in the following section.

In terms of the QAIT model, peer tutoring works because it impacts on three (and usually four) of the QAIT elements. It solves the problem of providing appropriate levels of instruction by totally individualizing instruction for each tutee. It increases incentive because students receive the undivided attention of a high-status individual whom they usually want to please, because their learning efforts are closely monitored, and because they receive frequent, immediate feedback on their work. Quality of instruction is increased, particularly when tutors are trained in programmed tutoring models, but also because the tutor can easily adjust the pace and content of instruction to the tutee's needs and the tutee can ask questions when he or she does not understand. Finally, when tutoring is done in addition to regular classroom instruction, allocated time for instruction is increased. Even when this is not the case, time-on-task is likely to be higher in tutoring than in whole-class instruction.

Cooperative Learning

Cooperative learning refers to instructional methods in which students work in small, heterogeneous learning groups. It differs from peer tutoring in several ways. First, students in cooperative learning are generally all of the same age, and are learning the material together. There are high, average, and low achievers in each group, but the high achievers are not formally designated as tutors for the low achievers. Instruction in cooperative learning initially comes from the teacher. The learning group's task is usually to master what the teacher has initially presented.

There are many forms of cooperative learning, but they can be grouped in two major categories. In _group study_ methods, all students are working together to learn the same content. In _task specialization_ methods, each group member is responsible for a different part of the group's task.

Research on group study methods indicates that this form of cooperative learning can be highly effective if two conditions are satisfied. First, the groups must be working toward a valued group goal, such as a group reward. Second, success in achieving this goal must depend only on the individual learning of every member of the group (Slavin, 1983 a, b). For example, in Student Teams-Achievement Divisions or STAD, students are assigned to four-member, heterogeneous teams. The teacher presents a lesson, and then students study worksheets relating to the lesson, attempting to ensure that all team members have mastered the concepts. Finally, the students are individually quizzed, and teams are rewarded with certificates or other recognition or rewards if their average scores exceed a pre-established criterion. In this way, the only way for teams to succeed is to make certain that their members have learned. Of thirty-five methodologically adequate studies of group study methods which (like STAD) used group rewards based on group members' individual learning, twenty-eight found significantly higher achievement for cooperative than for control treatments (Slavin, 1986c).

In contrast, evaluations of group study methods which did not use group rewards or based group rewards on the quality of a single team product have not been more successful than traditional methods (Slavin, 1983 a, b). One study done in a military training setting made exactly this comparison.

Hagman and Hayes (1985) conducted two experiments on teaching U.S. Army Equipment Records and Parts Specialists supply-related tasks as part of their Advanced Individual Training. In both experiments they found that trainees who worked in four-member groups and were rewarded (with free time) based on their group's average quiz scores performed significantly better than did trainees who received free time based on their individual scores only, regardless of whether or not they studied in groups. That is, in this as in many elementary and secondary school studies, simply working in groups was not enough; the group had to be rewarded based on the individual learning of its members.

Achievement effects of cooperative learning models using task specialization are less clear cut. Consistent positive effects in social studies have been found for one complex model of this kind, called Group Investigation (Sharan, Hertz-Lazarowitz, & Ackerman, 1980), but other methods, using task specialization such as Jigsaw Teaching (Aronson et al., 1978) have been less successful.

Cooperative learning impacts primarily on incentive to learn. By rewarding groups on the basis of their members' learning, students encourage their groupmates to exert maximum learning efforts. This incentive system also motivates students to engage in effective peer tutoring, translating the teacher's instruction into learners' language, thereby increasing quality of instruction. However, the most effective of all cooperative learning methods are Team Assisted Individualization in mathematics (Slavin, 1985) and Cooperative Integrated Reading and Composition in reading and writing (Madden, Stevens, & Slavin, 1986). In addition to the incentive provided by group rewards, these methods also impact on appropriate levels of instruc tion, as both combine individualization (or subgrouping) with cooperative learning. Both methods have produced gains on standardized tests twice as large as those produced by traditional methods of instruction.

Suggestive Accelerative Learning Techniques (SALT)

Suggestive Accelerative Learning Techniques, or SALT, is an instructional model derived from the work of Georgii Lozanov (1978), a Bulgarian psychologist. This approach is based primarily on the idea that by involving students in relaxation exercises, teaching mental concentration, and presenting information in a dynamic way, their capacity for learning will dramatically increase. The method uses what is in essence a mild form of hypnotism to increase receptivity to new information, and then uses methods similar to those used in advertising to get across the instructional "message." A SALT lesson begins with inducing relaxation, playing classical music, and then presenting material in a dramatic, forceful way. Later the material is reviewed and practiced independently or in small groups. Students may participate in a play or psychodrama to act out the new information, and quizzes are given frequently as self-assessments of learning.

While there is a good deal of research on SALT, this research is of mixed quality and is difficult to evaluate. Virtually all of it is published in the Journal of Suggestive-Accelerative Learning and Teaching, and therefore has not been subjected to the rigorous peer review typical of the journals published by the American Educational Research Association or other scientific organizations. The largest number of studies of SALT by far were authored or co-authored by the editor of the Journal, Donald Schuster. Some of the studies of SALT (e.g., Peterson, 1977; Schuster, 1976) compared SALT to control methods, where the SALT students received half of the instructional time received by control students. When the achievement results were not significantly different, the the authors claimed that this showed SALT to be twice as efficient as the control method. In fact, use of small samples and measures of unknown reliability ensure that any observed differences will be non-significant. Other SALT studies (e.g., Schuster & Ginn, 1978) fail to hold content constant, comparing gains in SALT on a test designed for the SALT teachers to gains in “similar” control classes which may have been teaching different objectives. Most SALT studies are either very brief or use very small samples, or both, and some had no control groups.

With all of these reservations in mind, the sheer volume of testimonial as well as scientific (though flawed) evidence supporting the use of SALT indicates that the method is at least worthy of independent evaluation. A few studies of SALT did attend to problems of making experimental and control groups comparable and holding both to the same objectives, and did find small but statistically significant advantages for the method (Prichard, Schuster, & Gensch, 1980; Schuster & Prichard, 1978). However, even if the effects of the method are taken at face value, it is by no means clear which elements of SALT account for its effects.

APPLICATIONS TO MILITARY TRAINING

The theories and research presented in this paper are derived primarily from studies done in elementary and secondary schools. The settings in which military training takes place differ in many ways from typical school settings. Military trainees are not only older, but they may be more motivated to learn, as there is likely to be a direct relationship between their success in training and their success in the military. The objectives of military training are often quite different from those typical of elementary and secondary schools; for example, many military tasks require hands-on, one-to-one training rather than classroom instruction. However, much of military training does involve instruction in classroom settings, and it is to this setting that the research discussed in this paper applies most directly.

The applicability of the specific methods discussed in the previous section to military training depends on the training objectives and the situation in which training takes place. For example, if a training program had clearly specified, easily measured objectives, then some form of mastery learning might be appropriate. If resources were available to provide corrective instruction outside of class to students who failed to achieve mastery on a formative test, then group-based mastery could be a very effective strategy. If trainees had considerable leeway in how they used their time outside of class, then the Personalized System of Instruction (Keller Plan) might be used. If it is appropriate to allow all trainees to take as long as necessary to master a set of information or skills, then some form of individualizized instruction might be effective.

One program that has actually been evaluated and found to be effective in military training is cooperative learning (Hagman & Hayes, 1985). Cooperative learning lends itself well to the military environment, which already emphasizes squad organization, cohesiveness building, and mutual interdependence. Cooperative learning has been combined with individualized instruction (Slavin, 1985) and with mastery learning (Mevarech, 1985), and the results have been more positive than for either method alone, so it may be that some form of cooperative learning could be incorporated with other instructional formats in military training.

The usefulness of peer tutoring in military training would depend once again on practical considerations. If more experienced or higher-ranking individuals are available to provide one-to-one instruction to trainees, this can be very effective. In particular, peer tutoring may be effectively used as corrective instruction in mastery learning programs.

The applicability of SALT to military training is uncertain. One study (Peterson, 1977) did evaluate SALT in Navy ROTC naval science classes and found results that were somewhat supportive of the method. However, the author notes that “many (students) would make fun of the (SALT) exercise before the lesson and distract those who were trying to concentrate. Some of the students thought the method was a hoax and generally were the troublemakers” (page 6). It is unclear that military trainees would take deep breathing and Baroque music seriously, although it would be worth experimenting with.

Beyond the particular methods, the principles outlined in this paper do apply just as well to military as to other instructional settings. Military training must emphasize well-organized, cognitively sensible instruction, it must take into account students' levels of prior knowledge and skills, it must provide incentives for learning, and it must provide adequate learning time. There is no magic in instruction. Producing effective, transportable instructional models is a matter of analyzing instructional objectives and mobilizing training resources to provide high levels of instructional quality, appropriate levels of instruction, strong incentives to learn, and adequate time for learning. These are the raw materials of effective instruction, and instructional design to meet any particular objective and setting is a question of engineering available resources to provide them.

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FIGURE 1

MODEL RELATING ALTERABLE ELEMENTS OF INSTRUCTION TO STUDENT ACHIEVEMENT