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ABSTRACT

Differences in semantic recall between students hypothesized as having either a high or a low analytic style were investigated. Styles were determined by the amount of bilateral alpha activity measured from the cerebral cortex of the brain during eyes-open baseline recordings. The results indicated that when expository text was tightly structured, high analytic subjects (those producing relatively less bilateral alpha than low analytic subjects) recalled more of the logically or semantically important information from text when compared to low analytic subjects. They also recalled some of the superordinate relative to subordinate information. Low analytic subjects, on the other hand, appeared to recall superordinate and subordinate information at approximately the same rate. The results provided support for the bimodal theory of cognitive processing. (Author/RL)

CENTER FOR THE STUDY OF READING

Technical Report No. 210

COGNITIVE STYLE DIFFERENCES IN EXPOSITORY PROSE RECALL

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Abstract

Differences in semantic recall between students hypothesized as having either a high or low analytic (holistic) style were investigated. Styles were determined by the amount of bilateral alpha (8-13 Hz) activity measured from the cerebral cortex of the brain during eyes-open baseline recordings. The results indicated that when expository text is tightly structured, high analytics (those producing relatively less bilateral alpha than low analytics) recall more of the logically or semantically important information from text when compared to low analytics. They also recall some of the superordinate relative to subordinate information. Low analytics, on the other hand, appear to recall superordinate and subordinate information at approximately the same rate. Results were discussed in relation to the bimodal theory of conscious processing and several suggestions for future research were provided.

Cognitive Style Differences in Expository Prose Recall

In recent years there has been renewed research interest concerning individual differences in cognitive processing (Carroll & Maxwell, 1979; Eysenck, 1977). Most of this research has used simple word lists as stimulus material (see Eysenck, 1977, chapters 8-12 for a review). Unfortunately, few studies have investigated cognitive style and personality differences as they relate to discourse processing (e.g., Wolk & DuCette, 1974), and even fewer of these have utilized the powerful semantic analysis procedures and text grammars that have recently been developed (Meyer, unpublished study cited in Meyer, 1977; Spiro, Note 1; Spiro & Tirre, Note 2). Although few in number, these latter cognitive-style experiments indicate that people identified as having differing personality or cognitive styles do not recall text in the same manner.

The present study investigated a "new" cognitive-style dimension that has evolved from what has been termed the <u>bimodal theory</u> of cognitive processing (Deikman, 1971, 1976; Dunn, in press; Ornstein, 1973, 1977). Bimodal theory, which should be viewed more as a set of organizing ideas than a fully developed theory, argues that the representation of information contained in long-term memory is influenced by the mode of conscious processing, analytic or holistic, used in encoding the information. The analytic mode is predominantly logical and sequential in its processing, while the holistic mode processes information in an intuitive and simultaneous or parallel manner. Similar notions have been expressed by Paivio (1971, 1975) in describing his dual coding theory of memory.

Many investigators (e.g., Galin, 1974; Levy-Agresti & Sperry, 1968; Ornstein, 1973, 1977; Patterson & Bradshaw, 1975) have argued that bimodal processing is hemisphere dependent, with the left cerebral hemisphere of the brain being specialized for analytic processing and the right being specialized for holistic processing. The role of the cerebral hemispheres in analytical and holistic processing has received support from studies using dichotic listening tasks (e.g., Kimura, 1964), visual half-field tasks (e.g., Barton, Goodglass, & Shai, 1965; Bryden, 1963; Geffin, Bradshaw, & Wallace, 1971) and research utilizing the electroencephlogram (EEG), (e.g., Bennett & Trinder, 1977; Doktor & Bloom, 1977; Doyle, Ornstein, & Galin, 1974; Osborne & Gale, 1976).

Of the three cortical assessment procedures the latter method appears to hold special promise for cognitive research because, unlike the others, it allows for on-line assessment of brain processing during the encoding of complex material including that encountered during reading. Also of interest for the present research, EEG activity, particularly in the alpha bandwidth (8-13 Hz), has been shown to be related to individual differences in cognitive style (e.g., Davidson & Schwartz, 1977; Doktor & Bloom, 1977; Ornstein & Galin, 1976). Davidson and Schwartz (1977), for example, found that musically non-proficient subjects showed significantly greater relative right hemisphere activation while whistling a song versus reciting the lyrics of a song; whereas musically proficient subjects did not show EEG asymmetry (using alpha ratios) between these tasks. Based on their results, Davidson and Schwartz concluded that musical training is associated with the adoption of a more sequential and analytical processing mode.

Differences in alpha activity have also been shown between occupational groups assumed to have different processing styles based on the nature of their profession (Doktor & Bloom, 1977; Ornstein & Galin, 1976). The study of Doktor and Bloom is of particular interest since some fairly clear differences were found between an occupational group assumed to have an analytical processing style (operations researchers) and another assumed to use a more holistic mode (corporate executives). These investigators gave both occupational groups two problem sets to complete during which bilateral alpha recordings were taken. One problem set contained verbal-analytical problems, the other more holistic, visual problems. The results showed that the analytical processors produced less alpha in the left hemisphere when solving verbal problems than when solving spatial ones. The executives, on the other hand, showed an inconsistent pattern with half producing alpha similar to the analyticals and the other half producing just the opposite pattern.

Because of the questionable choice of holistic thinkers, these results are not as clean as one would like them to be. While many executive positions do require people who focus more on wholes than on parts, many others require or attract persons who have a more analytical style (e.g., college faculty chairpersons). Thus, Doktor and Bloom's holistic thinkers probably contained a mixture of both types. Still, the results of their work are promising.

Sex differences in lateral specialization of hemispheric functioning have also been found (e.g., Davidson & Schwartz, 1977; Ray, Morell, Frediani, & Tucker, 1976). The Ray et al. study showed that when males and females were given right and left hemisphere cognitive tasks, the ratios of EEG power measured from the temporal lobes were statistically significant for males but not for females. These results suggest that males and females may process the same environmental stimuli with different patterns of brain activity. Since evidence of hemispheric processing differences between the sexes has also been indicated in visual half-field studies using words (e.g., Bradshaw, Gates, & Nettleton, 1977) as well as faces (e.g., Rizzolatti & Bushtel, 1977), it could be argued that sex of subjects should be a major variable of study.

Some recent evidence, however, indicates that both hemispheres may possess some analytical and holistic processing capability (e.g., Cohen, 1975; White & White, 1975). These studies, as well as an increasing number of others (Basso, Bisiach, & Capitani, 1977; Freides, 1977; Hardyck, Tzeng, & Wang, 1978; Heeschen & Jurgens, 1977; Levy & Trevarthen, 1976) suggest that analytical and holistic processing styles could best be viewed as unique products caused by different "mixtures" or interactions of the cerebral hemispheres, rather than separate functions of each.

In fact, many investigators have recently stressed the need for an integrative approach to hemispheric processing (Ben-Dov & Carmon, 1976; Broadbent, 1974; Hellige & Cox, 1976; Levy & Trevarthen, 1976; Luria & Simernitskaya, 1977; Trevarthen, 1978). For example, the results of the study by Levy and Trevarthen (1976) led them to conclude that information processing is organized by a metacontrol system which regulates hemispheric processing. They argue that cerebral lateral specializations pertain not just to the ability and manifest behavioral differences between the two sides of the brain, but also to the expectations of the metacontrol system as to the nature of the processing requirements. Further, the metacontrol system makes its decision prior to actual information processing, and the chosen hemisphere remains in control even if its performance declines because the metacontrol system has chosen the wrong hemisphere for the task, regardless of reason. This notion was used by these researchers to account for the numerous dissociations between hemispheric specialization and matching task performance exhibited by their commissurized patients. The dispositions of the metacontrol system to act are independent of, though usually correlated to some extent with, differential aptitudes of the hemispheres.

Of crucial importance for our research, Levy and Trevarthen conclude by stressing that not only is perception (encoding) an active, constructive process, but it is also highly dependent on the internal state of the subject, which in turn depends on constraints imposed by learned values, expectations, knowledge, and intentions. This view nicely parallels other bimodal theories (e.g., Deikman, 1971, reported below) and suggests that the metacontrol system of a given individual can be biased towards a particular mode because of past learning, culture, etc. This, of course, does not preclude the shifting of modal balance in an individual because of an unsuccessful outcome or because of the types of instructions they receive (e.g., Levy & Trevarthen, 1976; Hymes, Dunn, Gould, & Harris, Note 3).

Because of the growing controversy concerning the roles of the two cerebral hemispheres in cognitive processing (see Dunn, in press), our research has taken an approach that is not dependent on hemispheric differences in alpha activity, although they are measured. Rather than differentiating styles based on some ratio of right to left hemisphere alpha (where there have been some recent and notable failures to demonstrate consistent differential hemispheric activation, e.g., Arndt & Berger, 1978), the index used in the present research identifies cognitive style based on differences in the amount of summed, bilateral alpha activity measured across people.

The bilateral alpha score was suggested by Deikman (1971, 1976) whose bimodal model proposes that when a person uses the analytic mode of processing, his or her EEG is characterized by an abundance of beta activity (greater than 13 Hz.). In contrast, when that person utilizes the holistic mode of processing, the electrical brain activity consists largely of alpha waves (8-13 Hz.). Deikman, like many bimodal theorists (e.g., Ornstein, 1977) believes: (a) that people have two modes of processing, the analytical and holistic, that differ more qualitatively than quantitatively, (b) that they use both modes in processing information, and (c) that shifts in the balance of the two modes are quite common. We reasoned that if Deikman is correct, and people have two or more modes, then it is possible that differences in the balance of these modes may exist across individuals.

Even if Deikman (1971, 1976) and numerous psychologists (Cohen, 1975; Ornstein, 1973, 1977; Paivio, 1971, 1975; Patterson & Bradshaw, 1975; White & White, 1975) and neurophysiologists (e.g., Levy-Agresti & Sperry, 1968; Levy & Trevarthen, 1976) are incorrect, and what really exists is merely a continuum of analytical processing as Pylyshyn (1973) apparently believes, it is still possible that the amount of alpha typically produced by subjects is inversely related to the amount of analytic processing used for various tasks. That is, high alpha production could be indicative of people who typically (not exclusively) give a smaller weighting to analytic processing, whereas low alpha production could be used to identify those people who possess a highly analytic style.

Up to this point no one to our knowledge has collected enough data using holistic type tasks (e.g., the Street Gestalt Completion Test, Street, 1931) to assume that a largely holistic cognitive style exists. Thus, for the remainder of this paper the terms <u>high analytic</u> and <u>low</u>

analytic will refer to what has been previously termed analytic and holistic process..g styles.

Weakness of Past EEG Research

Amazingly, little of earlier reported research relating individual differences in modal processing to differences in brain activity has actually measured behavioral performance on the cognitive tasks used to elicit that activity. Differences in brain activity during task processing are interesting but could be considered of little practical or theoretical value unless that activity is consistently related to individual differences in task performance.

Our first attempt to investigate differences in bimodal processing as indexed by physiological brain activity (Hymes, Dunn, Gould, & Harris, Note 3) was a memory study which used measures of recall and clustering performance. It will be instructive at this point to relate this research in detail because the study was specifically designed to test some of the notions proposed by Deikman (1971, 1976) concerning physiological correlates of modal processing.

Since Deikman does not speak of differences in alpha asymmetry, but in terms of magnitude of alpha production, our early research reported immediately below did not address differences in hemispheric processing. However, the present research on prose memory did measure hemispheric differences. Given the new integrated view of bimodal processing, this is probably not a critical omission.

Subjects were divided into high analytics versus low analytics (holistics) on the basis of two minute, eyes open, integrated recordings of their right hemisphere alpha activity. Low analytic subjects were defined as those whose scores fell above the median; high analytic subjects were defined as those whose scores were below it.

After screening, subjects returned for a learning task. Half the subjects in the low and high analytic groups were instructed to relax and the other half to be alert during learning. This resulted in a 2 (type of processor: high/low analytic) by 2 (instruction: alert/relax) factorial design for data analysis. The learning task was similar to that used by Bousfield (1953) and consisted of a 40-item word list containing five difficult 8-word categories derived from the McConkie and Dunn (Note 4) word-sorting norms. The words were presented in quasi-random order, with no two members of the same category being contiguous. The list was shown twice using a slide projector, with each word presented individually for 5 seconds. After presentation the subjects were allowed 5 minutes to recall the list in any order they wished.

A two-way unweighted means ANOVA performed on the recall data showed only the main effect of type of processor to be statistically significant. Mean recall was greater for high than for low analytic subjects (20 versus 16 words, respectively). In order to determine if these styles encoded differently, the subjects' recall protocols were scored for the amount of obtained versus expected clustering (categorical organization) using a method reported by Bousfield and Bousfield (1966). Type of clustering score was treated as a repeated measure, and a three-way unweighted means ANOVA was performed on these data. Several main effects and interactions were found to be significant including the important two-way, processor by type of score, and the three-way interaction. These interactions, coupled with appropriate $\underline{F}$ tests for simple effects, showed two unique patterns: high analytic subjects produced significant clustering, whereas the clustering of low analytics was no better than chance. In addition, high analytic subjects given alert instructions produced higher mean clustering than the other conditions.

Subjects' recall data were then plotted as a function of the serial position of the words during presentation. The curve generated by the low analytics showed the typical serial position effect; however, because of their clustering, the high analytic subjects' curve did not. This indicates that the low analytic subjects encoded the information more in the order in which it was presented than did the high analytic subjects, who tended to organize the material into categories.

The results of this study provide support for bimodal consciousness theory and show that at least one of the physiological measures suggested by Deikman (1971, 1976), the EEG alpha band, can be used to identify students who are relatively more analytical than others in their processing. Further, it appears that the use of relaxation and alert instructions can differentially shift the modal balance used by subjects.

Some investigators may prefer to view the differences we have ascribed to differences in bimodal processing as due to differences in "arousal" level. However, the old notion that alpha is a correlate of simple arousal and follows the traditional inverted u-shape function was seriously questioned in a clever set of experiments reported by Orne and Wilson (1977) who showed that, among other things, subjects can produce high alpha even under conditions of high stress. (The interested reader will find many other arguments against the simple arousal notion in the article as well as evidence for systematic individual differences in alpha production.) Further, "arousal" is a very generic and somewhat nebulous term covering a wide range of human functioning including motivation and emotional behavior. It clearly does not describe the disparate recall patterns (and inferred differences in cognitive processing) that can be accounted for using our dichotimization. That is, to assume that our high analytic subjects are just highly aroused, not only does not adequately represent their logical and categorical patterns produced at recall, but also implies that "arousal" is somehow a direct agent. It is just as easy to assume that measurements of "arousal," such as the alpha band, are merely the correlates of higher-order cognitive processes, rather than the other way around. This latter assumption is, of course, the one taken in this paper.

These findings are also particularly promising since college students were used as subjects. It could be argued that, if anything, college students are more analytical than most other people because of their academic characteristics and training. It appears, then, that the type of processing used by subjects may be a powerful variable determining which types of information will be learned, how it will be encoded, and how it will be recalled.

The present research represents a first attempt to extend bimodal processing theory to the difficult area of memory for complex prose. In order to gain more power, several of the major weaknesses inherent in our previous work (Hymes et al., Note 3) were corrected: (a) Dichotimization of high or low analytical processors was based on the average amount of alpha activity produced by both the right and left hemispheres during the baseline period, rather than based solely on the integrated activity from the right hemisphere. Note that the practice of averaging across hemispheres is in harmony with Deikman's views concerning the use of alpha as a correlate of bimodal processing. It is also consonant with the other integrative approaches (presented earlier) which suggest that both hemispheres are involved in analytical as well as holistic processing; (b) The power in the alpha band was determined by a Fourier analysis of the EEG spectrum (1 to 50 Hz.) which is far more accurate than most simple integrations using an alpha bandpass filter; and (c) EEG recordings were taken during the experimental task and subsequently analyzed using the Fourier procedure in order to determine if the alpha activity of high versus low processors continues to differ while the subject is reading and recalling expository text.

The specific purpose of our most recent research was to test whether individual differences in modal processing style affect the type, and perhaps even the amount, of semantic information encoded and recalled from expository text. Expository text was used because it is generally more semantically complex than narrative discourse, consequently requiring increased analytical processing. Such text, then, should maximize the differences in processing (as measured by free recall) of those persons identified as having a highly analytic, versus a less analytic (perhaps holistic) cognitive style.

One of the major advantages of several of the new semantic grammars (e.g., Kintsch, 1974; Meyer, 1975) is that they can identify the pattern of subordination of semantic information contained in text, regardless of where it physically occurs in the passage. In the case of Meyer's (1975) content-structure grammar, the type of relationship between this information is also described, typically by using rhetorical predicates (Bieger & Dunn, Note 5).

Armed with these tools, it is quite possible to investigate whether the major hypothesized difference between high analytic and low analytic processors, i.e., that they have different processing strategies which produce different memory structures has any validity when complex text information is learned. If the hypothesis is true, it could be expected that high analytics, because of their categorical and logical style (Deikman, 1971, 1976; Hymes, et al., Note 3) should recall more of the superordinate information of a passage when compared to low analytics who may possess a more gestalt or holistic processing style. Further, based on the results of Hymes et al., learning instructions should differentially shift the modal balance used by these two groups, thereby affecting their recall performance. That is, each group should perform best with instructions appropriate for their mode; with high analyticals' greatest performance occurring when instructed to concentrate, and low analytics' when asked to relax. In order to test these and other notions, the following experiment was undertaken:

Method

Subjects and Physiological Recording Techniques

Bilateral EEG measurements were taken from 40 upper-division university students during a baseline period and during subsequent reading and recall tasks. Recordings were made using a Glass Model 7 polygraph and were stored on paper and on magnetic tape, with the latter being recorded using a Tanberg Series 100 instrumentation FM recorder. Prior to running each subject the polygraph was internally calibrated. Further, the complete recording system was checked periodically by sending a 10 Hz. signal through the electrode leads into the polygraph and the tape recorder. The tape recorded EEG data were later analyzed into conventional frequency bandwidths using a Hewlett-Packard 5441 Fourier analysis computer. Power in the alpha bandwidth was used as the brain activity correlate in this experiment.

The recordings were made from two parietal temporal sites; i.e., from a point midway between P_3 and T_3 on the left hemisphere, and midway between P_4 and T_4 on the right, in accordance with the 10-20 Electrode System (Jasper, 1958). Both sites were referred to C_z because it allowed for eventual comparison with past research which also used this reference (e.g., Doyle, Ornstein, & Galin, 1974). Since good electrode contact is essential for maximizing the signal-to-noise ratio, contact impedance was checked just prior to and immediately after the experimental tasks.

General Procedures

After electrode placement, the subject was asked to sit quietly for 10 minutes because previous research has suggested that a rest period facilitates alpha production (e.g., Paskewitz & Orne, 1973). The baseline EEG records were made during the last 2 minutes of this pericd. Immediately after the baseline was taken, half the subjects, randomly chosen, was instructed to be alert and to concentrate as much as possible during the reading and recall tasks which followed. The other half was instructed to remain as relaxed as possible. Each subject was given three passages to read, with a written recall following the presentation of each passage. (Again, physiological recordings were taken during this period.) Passages were reproduced on 35mm slides and were rear-projected onto a screen placed directly in front of the subject. The two shorter passages were placed on a single slide each. The longer breeder reactor passage was reproduced on three slides, with each paragraph contained on a separate slide.

Subjects initiated the reading/recall sequence for each passage by pressing a button to present each slide. They were instructed to read at their normal rate and, when finished, to press the button again. They were then asked to immediately write down what they could remember about the passage in any order they wished and to push the button again after they finished their recall. Clocks and printing counters were programmed to each button press, allowing reading and recall time data to be recorded. A rest period of 3 minutes was given after each passage reading/recall sequence. After these tasks were completed, subjects were released and informed as to the nature of the experiment.

Specific Nature of the Passages

Table 1 contains the three experimental passages. The two shorter passages were used in previous research by Kintsch and his associates

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Insert Table 1 about here.

(Kintsch, Kozminsky, Streby, McKoon, & Keenan, 1975). Both passages had approximately the same number of words and semantic propositions but differed on the number of different arguments contained in those propositions. According to the results of Kintsch et al. (1975), the asteriod passage, which contained fewer different arguments, should be recalled better and take less reading time than the sea floor passage, which contained many more different arguments in its semantic (text) base.

The third, longer passage, concerning nuclear breeder reactors, was derived from one used originally by Meyer (1975). It should be noted that this passage is not only longer than the others but also has considerably more internal structure. That is, it is semantically "tighter" in that specific problems and a possible solution are offered. In contrast, the Kintsch passages basically contain a listing of attributes and details. This observation has also been made by Meyer (Note 6).

General Design

Dichotomization into high or low analytic processors was based on the subjects' baseline alpha production summed across the two hemispheres, because of past research which has shown that EEG activity is a direct correlate of processing style (e.g., Doktor & Bloom, 1977; Hymes, et al., Note 3). Holistic subjects were defined as those whose summed alpha production exceeded the median, whereas analytical subjects were defined as those whose scores fell below it.

As previously mentioned, there is mounting evidence that there are sex differences in hemispheric activity (Ray, et al., 1976) and that these differences may be related to performance (Rizzolatti & Bushtel, 1977). There are also several prose memory studies which have shown sex differences in prose recall (Dunn & McConkie, 1972; Frederiksen, 1975a, 1975b). For these reasons, sex was treated as an independent variable in the statistical analysis performed on both the physiological and prose recall data.

In summary, this resulted in a general 2 (sex) by 2 (type of processor: high/low analytic) by 2 (instructions: concentrate/relax) factorial design. Because dichotomization into high and low analytic processors was made after all subjects were run and the experiment completed, unequal cell sizes were produced. The unequal cell sizes were, of course, accounted for in the statistical analyses of the data presented below.

Results and Discussion

Recall Scoring Procedures

Subjects' numerically coded recall protocols were scored independently by two of the experimenters. The recall data from the two short asteroid and sea floor passages were scored against both the Meyer content-structure and the Kintsch text-base analyses of that particular passage's semantic content. The recall scoring procedures followed those suggested by Kintsch et al. (1975, p. 201) and Meyer (1975, pp. 99-201). However, for brevity and because the analysis of the present data showed that the Meyer (1975) grammar was more sensitive to subtle individual differences in semantic recall than the Kintsch grammar, a finding supported by past research (Bieger & Dunn, Note 5), only the Meyer scored data will be reported here.

Briefly, when Meyer's system is used to analyze text, it produces a single hierarchically arranged tree structure called the content structure. The content structure is composed of the words from the text, specified case roles (similar to the case grammar of Fillmore, 1968), and a series of terms which explicate the nature of the logical relations between propositions (the rhetorical predicates of Grimes, 1975). All of these elements are termed idea units because all provide some level of semantic description.

The content structure illustrates the pattern of subordination of ideas in a passage. The top-level or superordinate ideas typically have many levels of subordinate ideas related to them which are shown by direct downward paths in the structure. Top-level ideas dominate their subordinate ideas, whereas the lower-level ideas generally describe or give more information about the ideas above them.

Meyer's system not only produces a pattern of subordination among ideas in a passage, but it also describes or labels the relationships among the ideas. She argues that a prose passage can be viewed as a complex proposition that can be subdivided into subpropositions bearing certain relations to one another. (This is analogous to the macrostructure described by Kintsch and van Dijk, 1978.)

Meyer describes two types of predicates: lexical predicates and rhetorical predicates. Lexical predicates are content words from text, usually verbs and their adjuncts, which take other words contained in the text as arguments. The relationship between the lexical predicate and its arguments are described by case or role relations similar to those described by Fillmore (1968). Rhetorical predicates consist of a finite number of labels and are often found at the higher levels of the content structure and generally describe the overall organization of the text. They are used to describe how various subordinate ideas are related. A rhetorical proposition has a rhetorical predicate and, although it could have a single item from text as an argument, it typically takes entire lexical propositions or other rhetorical propositions as its arguments. In other words, rhetorical predicates are usually used to specify the relationship among larger segments of text rather than segments of simple sentences. These larger segments may include entire paragraphs or chapters of text. Lexical predicates, on the other hand, are generally used to relate intrasentence items. Utilizing this prose structure as a standard, subjects' recall of a given prose passage was compared to the content structure of that passage. Given the complexity of the recall data, scoring reliability was acceptably high, averaging 91% across passages.

Because the two brief passages contained approximately the same number of words and propositions, but differed on the number of different arguments each contained, the recall data of these two passages were treated as a repeated measure in the following statistical analyses. The recall data for the lengthier breeder reactor passage, however, were analyzed separately because it had more internal coherence and differed in the number of levels of subordination when compared to the two shorter passages.

Meyer Recall Data

For the primary purpose of determining if high and low analytic processors differ on the total number of semantic propositions recalled, the total number recalled from the two short passages was analyzed using a four-way, mixed analysis of variance. The independent variables were sex, type of processor, instructions, and passage, which was a repeated measure. The only main effect which reached statistical significance was instructions, $F(1,32) = 5.75$, $p < .03$, with concentration instructions producing greater mean total propositional recall (12.1) than relaxation instructions (9.5). The two-way sex by passage interaction was the only interaction found to be significant, $F(1,32) = 5.96$, $p < .02$, indicating that females' total recall decreased very slightly with the few-argument asteroid passage, compared to the many-different-argument sea floor passage (few 10.81 versus many 10.15); males, on the other hand, showed the opposite pattern (few 10.35 versus many 11.9).

When the total propositional recall data from the longer, but more semantically structured breeder reactor passage were analyzed using a three-way analysis of variance (sex, type of processor, instructions), the main effect of type of processor was the only source of variation to reach even marginal significance, $F(1,32) = 3.67$, $p < .07$, with high analytics mean total recall being slightly greater than low analytics (22.7 versus 18.3). Although weak, this finding is similar to the significant word-list recall results of our earlier study (Hymes, et al., Note 3).

In spite of these marginal results, the most important prediction for bimodal theory, as presented here, is that high and low analytic processors form and subsequently recall information using different memory structures. Specifically, this would be indicated if high analytics were found to recall more of the superordinate information contained at the higher levels of the semantic structure of a passage than were the low analytics. In order to test this notion, the number of idea or semantic units (propositions and their related predicates and arguments) recalled by each subject at each level of subordination in the passage's content-structure was converted to the proportion of the total number of units possible at each level of that structure. The content-structure analyses of both short passages produced five levels of subordination each. The semantic analysis of the more organized breeder reactor passage produced four levels.

The proportional recall data of the two short passages were analyzed first using a five-way mixed analysis of variance. The two repeated measures for this analysis were passage and levels in the content structure, and the three between variables were again: sex, type of processor, and instructions. The main effects of passage, $F(1,32) = 32.49$, $p < .001$, and levels, $F(4,218) = 94.50$, $p < .001$, were highly significant, with the few-different-argument asteroid passage having greater mean proportional recall (.38) than the many-different-argument sea floor passage (.24). The levels main effect showed the typical pattern, with the more superordinate idea units being recalled at a higher proportion on the average than the lower level items (.62; .45; .26; .22; .04, respectively). Both these results are in keeping with the earlier findings of Kintsch et al. (1975), and the latter, with those of Meyer (1975) and Thorndyke (1977).

Two of the two-way interactions were also significant, the sex by levels, $F(4,128) = 3.88$, $p < .005$, and the passage by levels interaction, $F(4,128) = 14.81$, $p < .001$. The sex by level interaction indicated that females tend to recall proportionally more items from the superordinate levels than do males. The passage by levels interaction showed that the few-argument passage produced the typical levels effect, whereas the many-different-argument passage produced a less consistent pattern (.38; .42; .20; .16; .04). The second level of subordination, for example, had slightly greater mean proportional recall (.42) than the highest level of subordination (.38). This interaction, coupled with the main effect of passage, suggests that of the two, the many-different-argument passage was the more difficult to comprehend, thus replicating the results of Kintsch et al. (1975).

Of greater importance is the significant three-way passage by sex by type of processor interaction, $F(1,32) = 4.84$, $p < .04$, which is shown in Table 2 as two-way interaction components for ease of interpretation.

Insert Table 2 about here.

It appears from these data that male low analytics have approximately the same low mean proportional recall from either passage. In contrast, the subjects in the other conditions appear to have greater mean proportional recall of the few-argument passage, relative to the one containing many different arguments, suggesting possible sex differences in modal processing.

As promising as these results are, they are not strong evidence that high analytic and low analytic processors encode and recall using different organizational patterns or memory schemata. What was needed was some interaction involving the variables of type of processor and levels of the content structure. A possible reason for the lack of interaction may have been the two short passages used, since neither had a great deal of semantic structure. This would tend to make both of them difficult to comprehend. It could be possible that high analytics, because of their hypothesized logical skill, show differential recall of superordinate information when the text is more logically or semantically organized than were either of the two short passages.

This speculation basically was confirmed by the proportional recall data from the third, more semantically organized, breeder reactor passage. These data were analyzed using a four-way mixed analysis of variance, with levels in the content structure serving as the repeated measure. The levels main effect was again highly significant showing the now typical pattern of higher recall of superordinate, relative to subordinate information. Further, although the main effect of type of processor did not reach significance ($p < .07$), the highly important three-way type of processor by instructions by levels interaction was found to be highly significant, $F(3,96) = 5.11$, $p < .003$.

The propositional recall data contributing to this interaction are shown in Table 3, where it appears that high analytics, particularly when asked to concentrate, recall proportionally more of the superordinate items than those at lower levels; whereas low analytics, when asked to concentrate, do not recall as much high-level information. Also, when

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Insert Table 3 about here.

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low analytics are asked to relax during the reading and recall tasks, they appear to have considerably lower recall of the lower level items, as compared to when they are asked to concentrate. High analytics, on the other hand, tend to produce the same basic, declining pattern regardless of instructions. These findings were confirmed by tests of simple interaction effects and related simple main effects (Kirk, 1968, pp. 289-294), thus lending credence to the notions presented at the first part of this section; namely, that high analytics would tend to recall more superordinate information than low analytics, and that the recall patterns of the two types of processors would be differentially affected by the learning and recall instructions they were given.

Further, partial confirmation of these results is provided by comparing the mean proportional recall data of the two shorter passages as a function of type of processor, instructions, and levels in the content structure. Although the necessary four-way interaction (type of processor by instructions by passage by levels in the content structure) did not reach statistical significance ($p < .09$), the data are shown for comparison purposes in Table 4.

Insert Table 4 about here.

It will be recalled that of the two shorter passages, the asteroid passage was the more semantically structured and, therefore, the more easily comprehended. Thus, if our earlier speculations are correct (i.e., that high analyticals, when asked to concentrate, will show greater recall of superordinate information than low analytics), it could be expected that the recall pattern of the asteroid passage produced by these two groups should be similar to the significant pattern found with the highly structured breeder reactor passage, reported above. In contrast, the recall pattern of the extremely loose sea floor passage should not show an advantage for high analytical processors. As can be seen from the data in Table 4, these recall patterns are basically as predicted.

Before concluding, it is important to note that although increased time spent reading or rehearsing the passages by the high analyticals could have caused some of the positive differences in their recall data, the analysis of the reading-time data showed that low analytics actually spent slightly more time reading than did high analyticals. (For the sake of brevity these data are not reported.) A similar finding also occurred with the recall-time data. More importantly, when reading time was statistically controlled using analyses of covariance, the results of the total, as well as the proportional recall data just reported, were virtually unaffected.

In summary, these results, particularly the significant three-way interaction with the breeder reactor data, strongly suggest that individual differences in bimodal processing affect the encoding (inferred from recall) as well as the type of semantic information recalled from complex text. The results also generally replicate the findings of the Hymes et al. (Note 3) study which also obtained recall pattern differences as a function of bimodal processing style and instructions. Thus, they imply that these effects are not limited merely to simple stimulus material.

Reading and Recall Alpha Data

As previously mentioned, bilateral EEG recordings were taken from subjects during the reading and recall tasks they were given. Since the time spent reading and recalling the passages varied across subjects, the total amount of alpha activity recorded from each cerebral hemisphere was divided by the total amount of time spent at that task. This of course "normalized" the data and allowed the reading and recall alpha data to be analyzed across all three passages using a separate analysis of variance for each.

Reading alpha data. The bilateral alpha data generated by each subject during reading were analyzed using a five-way mixed analysis of variance having three between independent variables (type of processor, sex, and instructions) and two within or repeated measures (hemisphere and passage).[1] Three main effects, type of processor, passage, and hemisphere, were found to be highly significant, $\underline{F}(1,32) = 14.41$, $\underline{p} < .001$; $\underline{F}(2,64) = 11.51$, $\underline{p} < .001$; $\underline{F}(1,32) = 12.73$, $\underline{p} < .001$, respectively. There was less mean alpha in the recordings from high (1.26) than low analytics (3.10), and post hoc testing confirmed that less mean alpha was found during the reading of the most semantically structured passage (breeder reactor) relative to the other two passages breeder reactor = 1.16; sea floor = 2.48; and asteroid = 2.96. Note that alpha values are expressed in relative power units.

Surprisingly, more mean alpha was generally recorded from the left hemisphere than the right during the reading tasks (2.43 versus 1.93). This result, although contrary to some other research (e.g., Doyle et al., 1974) appears to be primarily a function of the P/T recording sites used in our research and was not due to any equipment malfunction. Confirmation of this finding comes from a recent master's thesis conducted in our laboratory (Hunt, Note 7) and from an independent study by Ehrlichman and Wiener (1979). Both studies were similar to ours in that the same recording sites were used and EEG activity was recorded during the performance of verbal tasks. In both cases, the left hemisphere was shown to produce more alpha power or amplitude than the right hemisphere.[2] The neurophysiological explanation for this disparate activity is left for future research and is not of crucial importance for arguments made here because none of our predictions were dependent on any differential activity being recorded from the two cerebral hemispheres. Our subjects were labeled as either high analytic or low analytic processors based on the magnitude of summed alpha production from both hemispheres, rather than on alpha, either alone, or some ratio of one to another. However, for the interested reader the alpha data produced when reading each experimental passage are shown as a function of type of processor and hemisphere in the top half of Table 5.

Insert Table 5 about here.

The only interactions to reach significance were the three-way sex by instruction by passage interaction, $F(2,64) = 5.09$, $p < .009$, and the four-way type of processor by sex by instruction by passage interaction, $F(2,64) = 5.45$, $p < .006$. Although rather complex, examination of the four-way interaction suggested that most of the variation was caused by a large increase of alpha activity recorded from male, low analytics, instructed to relax, when they read the highly structured breeder reactor passage. Over 25% more alpha was recorded from these subjects when reading this passage as compared to the other two passages. In contrast, less alpha was recorded from subjects in the other conditions when reading this passage, relative to their activity during the reading of the other two passages.

Recall alpha data. The alpha data recorded at recall were compared using the same type of analysis of variance as used with the reading alpha data above. In most cases similar patterns were found (see bottom half of Table 5). The main effects of type of processor, passage, and hemisphere were again found to be highly significant and were in the same direction as the reading alpha data, $F(1,32) = 9.96$, $p < .003$; $F(2,64) = 7.69$, $p < .001$; $F(1,32) = 12.54$, $p < .001$, in that order. Less mean alpha was recorded from high analytics than low analytics (.72 versus 1.24), and less mean alpha was recorded during the recall of the breeder reactor passage (.76) than during the less structured sea floor (.93) or asteroid (1.25) passages. Like the reading alpha data, recorded left hemisphere alpha was greater than the right (1.16 versus .79) during recall.

Only the two-way type of processor by instructions, $F(1,32) = 7.78$, $p < .009$, and the three-way type of processor by sex by instruction, $F(1,32) = 7.77$, $p < .009$, interactions reached statistical significance. The two-way interaction showed than when high analytics were asked to relax less alpha was recorded than when they were asked to concentrate (concentrate = 1.13 versus relax = .39); in contrast, low analytics mean recorded alpha increased when asked to recall in a relaxed state (concentrate = 1.09 versus relax = 1.39). However, examination of the significant three-way interaction indicated that the low analytics' increased alpha under relaxation instructions was produced by the females (concentrate = .99 versus relax = 1.63), rather than by the males (concentrate = 1.16 versus relax = .93).

Albeit somewhat messy and in need of further examination, the interactions occurring with both the reading and recall alpha data suggest that possible sex differences in modal processing exist, particularly with relaxation instructions. Regardless of these interactions, the remarkable and consistent differences in alpha activity found between high and low analytic subjects across tasks is highly important, and in fact crucial, for the arguments made in this paper; i.e., that total power from the alpha band when measured at baseline can be used to reliably identify different cognitive styles. The relative difference in the magnitude of alpha activity recorded at baseline between these two groups appears to be maintained even during the subsequent performance of complex cognitive tasks. This "between subjects" consistency in recorded alpha does not appear to be temporary either Subjects have been shown to maintain their relative positions (using the same P/T and C_z recording sites) over two sessions containing verbal and spatial tasks, with at least one week separating the sessions (Ehrlichman & Wiener, 1979). This suggests that power in the alpha band is a stable correlate of processing style. These results are in keeping with Deikman's (1971, 1976) bimodal theory, as well as our previous findings (Hymes et al., Note 3) and are not best described by differences in "arousal" level (see discussion on pages 10-11).

Summary of Results

The data from our experiment, when taken together, begin to offer some support for the basic tenets of bimodal theory. The recall results, using Meyer's (1975) content-structure analysis of text, indicate that highly analytical processors tend to recall slightly more semantic information (propositions); but more importantly, they appear to encode and subsequently recall information using a different and more logical pattern than do low analytics. Like past research (e.g., Hymes et al., Note 3), instructions again appeared to cause shifts in the mixture of bimodal processing and there was some indication of sex differences in recall.

Also, analyses of subjects' EEGs showed that the recordings of high analytic processors contained less bilateral alpha activity than that of low analytics during the reading and recall tasks, indicating that power in the alpha band is a reliable physiological correlate of modal processing style. Several interactions occurring with these data suggest possible sex differences in bimodal processing; the explanation for these interactions is, however, far from clear at this stage of research.

Even though our research is promising, considerably more work needs to be done in order to test the overall predictive power of bimodal theory, particularly as it applies to the learning and memory of complex information. For example, the above study was limited to the reading and recalling of expository discourse-tasks which, it could be argued, are highly analytical in nature. It would be interesting to determine if these results would hold if narrative text or poetry were utilized as stimulus material. Given the description of low analytic (perhaps holistic) processors presented earlier, one might expect better performance from low analytics than from high analytics when given these latter types of text. One clear prediction derived directly from bimodal "memory" theory, and demanding investigation, is the notion that low analytic processors should show better performance on tasks postulated to require spatial or gestalt-type processing (e.g., perceptual tests like cube comparisons or hidden patterns, etc.).

Admittedly needing a great deal o xpansion, our research also has an important implication for memory theories in general, particularly those theories like schema theory (e.g., Rumelhart & Norman, 1978)[3] and levels of processing theory (Craik & Lockhart, 1972) which either play down or ignore individual differences in cognitive style. This paper will, therefore, conclude with a brief discussion of this issue.

General Implications and Conclusions

Traditionally, the incorporation of individual differences into the major theories of learning and memory has been avoided because of the assumption that these theories should be abstract enough to describe universal cognitive functioning. Therefore, the study of individual differences has been relegated, at best, to a secondary and somewhat unprestigious position in the learning field. This is quite surprising given the wealth of research literature showing that people having differing personality styles, like field-dependence (see Goodenough, 1976 for a review) and extraversion (see Eysenck, 1976), as well as processing styles (Hunt, 1978; Hymes et al., Note 3) do not behave in the way that various "universal" models of long-term memory would predict.

The irony is that such universal theories will probably continue to be shown to have little applicability to "real" problems, such as reading instruction and remediation, because of their stated strength of universality. Many of these theories are, in fact, too over-generalized, and thus too simplified, to have major predictive power in a large portion of individual cases. Admittedly overstating the case, the descriptions of encoding and retrieval processes by the current major theories of memory, like levels of processing theory (Craik & Lockhart, 1972), are analogous to a bureaucrat's description of the average American family which owns an 1101.32 sq. ft. house and contains 1.5 children. While there is some limited use for data like these, it is obvious that no family has exactly this hypothetical combination of attributes. Even schema prose theory, which does allow for various cultures to have differing general story schemas (e.g., Kintsch, 1977), falls into the same trap by stating little about individual coding differences within a given culture.

The question then becomes how much attention should be paid to individual differences, particularly in theories related to memory of text. It is possible, for example, that too much attention to minute differences may actually create problems of its own by producing theories too detailed and cumbersome to be of much use. Therefore, some compromise between the extreme positions concerning the study of individual differences is needed--the very least of which should include the identification and the incorporation of major classes of individual differences into our future models of memory. Hopefully, the classifications of analytical and holistic processors made in this paper will be of some use for theorists who attempt this difficult task. Regardless, the era of "benign neglect" needs to come to a close.

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Footnotes

The research reported herein was based, in part, on a chapter written by B. Dunn entitled "Bimodal Processing and Memory from Text," which will appear in V. M. Rentel and S. Corson's (Eds.) Psychophysiological Aspects of Reading, London: Pergamon Press Ltd. Appreciation is expressed to Pergamon Press for allowing us to report it here. This technical report was prepared while B. Dunn was supported as a visiting scholar at the Center for the Study of Reading, University of Illinois, by the National Institute of Education under Contract No. HEW-NIE-C-400-76-0116.

[1] Note that at least from the recording sites used, the reading and recall alpha data analyses showed that hemisphere did not significantly interact with any of the other independent variables. It is also of some interest to point out that several of the traditional ratio measures and difference measures (e.g., RH/LH) between the two hemispheres' alpha activity have been calculated. None, however, provided any more information than did our summed power measurements.

[2] The use of an active reference site can cause possible problems in assessing differential hemispheric activity. When an active site like C_z is used, an increase in recorded alpha activity does not necessarily reflect an increase in generated alpha. That is, an increase in recorded alpha may only reflect an increased difference in alpha generated at the site of interest (in our case the P/T sites) and the reference site. This increased difference could be produced by an increase or decrease at either site, or by changes in the phase relationships between sites, etc.

While still a possible problem for those interested in hemispheric activity, a recent study by Amochaev and Salamy (1979) found only slightly larger task-related EEG asymmetries when a "neutral reference site (ipsilateral ears) was compared with the active $\underline{C}_z$ reference.

[3]Rumelhart and Norman (1977) do pay lip-service to individual differences in their influential version of schema theory by stating that various individuals can have different schema concerning the same topic. Unfortunately tney do not explain whether these different schema merely contain different material, whether they contain different rules or strategies for processing new information, or whether they contain both.

Table 1

Experimental Passages Used in Bimodal Study

Passage with the Least Semantic and/or Logical Structure
(From Kintsch et al., 1975)

New sea floor and mantle are currently being added to the crust of the earth at spreading centers under deep-sea ridges. The sea floor spreads laterally away from these centers and sinks into the interior of the earth in deep-sea trenches. Volcanoes are created by the consumption process and flank the trenches. Thus, the volcanoes mark the borders between the plates which comprise the shell of the earth.

Passage with More Structure
(From Kintsch et al., 1975)

Asteroids are miniature planets that orbit around the sun. Hundreds of asteroids have been identified, but it is difficult to keep track of them, since all asteroids are alike. An asteroid is identified only by the position of its orbit. Even after an orbit has been determined, it is often lost because the orbit changes due to the influence of the large planets which deflect the asteroid from its orbit.

Passage with the Most Semantic Structure
(Modified from Meyer, 1975)

The need to generate enormous additional amounts of electric power while at the same time protecting the environment is taking form as one of the major social and technological problems that our society must resolve over the next few decades. The Federal Power Commission has estimated that during the next 30 years the American power industry will have to add some 1,600 million kilowatts of electric generating capacity to the present capacity of 300 million kilowatts. As for the environment, the extent of public concern over improving the quality of air, water, and landscape hardly needs elaboration.

A related problem of equal magnitude is the rational utilization of the nation's finite reserves of coal, oil and gas. In the long term they will be far more precious as sources of organic molecules than as sources of heat. Moreover, any reduction in the consumption of organic fuels brings about a proportional reduction in air pollution from their combustion products.

Table 1 (Cont.)

The breeder type of nuclear reactors holds great promise as the solution to these problems. Breeder reactors produce more nuclear fuel than they consume; they would make it feasible to utilize enormous quantities of low-grade uranium and thorium ores dispersed in the rocks of the earth as a source of low-cost energy for thousands of years. In addition, these reactors would operate without adding noxious combustion products to the air.

Table 2

Mean Proportional Semantic Recall as a Function

of Type of Processor, Sex, and Passage,

Scored Using Meyer's Text Analysis Procedure

Type of Processor	n	Passage	
		Few Argument	Many Argument
High Analytics			
Females	10	.41	.26
Males	10	.41	.24
Low Analytics (Holistics)			
Females	10	.44	.21
Males	10	.30	.27

Table 3

Mean Proportional Semantic Recall of "Tightly" Structured Breeder Reactor Passage as a Function of Type of Processor, Instructions, and Levels in the Context-Structure, Scored Using Meyer's Procedure

Type of Processor	n	Levels in Content-Structure 1	2	3	4
High Analytics					
Concentration Instructions	9	.67	.28	.24	.17
Relaxation Instructions	11	.52	.29	.22	.23
Low Analytics (Holistics)					
Concentration Instructions	11	.39	.33	.24	.23
Relaxation Instructions	9	.49	.20	.08	.09

Table 4

Mean Proportional Semantic Recall for the Two "Short" Passages as a Function of Type of Processor, Instructions, and Levels in the Semantic Content-Structure, Scored Using Meyer's Procedure

Type of Processor	$\underline{n}$	Levels in Content-Structure[a] 1	2	3	4	5
"More" Structured "Asteroid" Passage (From Kintsch et al., 1975)						
High Analytics						
Concentration instructions	9	1.00	.58	.34	.31	.00
Relaxation instructions	11	.82	.47	.25	.30	.00
Low Analytics (Holistics)						
Concentration instructions	11	.72	.50	.24	.19	.00
Relaxation instructions	9	.89	.36	.28	.18	.11
"Least" Structured "Sea Floor" Passage (From Kintsch et al., 1975)						
High Analytics						
Concentration instructions	9	.33	.48	.30	.17	.00
Relaxation instructions	11	.39	.33	.17	.10	.09
Low Analytics (Holistics)						
Concentration instructions	11	.41	.48	.26	.20	.04
Relaxation instructions	9	.37	.44	.09	.15	.00

[a] Levels in Content-Structure was a Repeated Measure

Table 5

Mean Alpha Power Recorded During Reading and Recall,

as a Function of Type of Processor, Hemisphere, and Passage

Type of Processor	Passage		
	Asteroid	Sea-Floor	Breeder Reactor
Reading Alpha Data[a]			
High Analytics			
Left hemisphere	1.96	1.71	.73
Right hemisphere	1.59	1.12	.46
Low Analytics (Holistics)			
Left hemisphere	4.29	3.90	1.98
Right hemisphere	3.79	3.18	1.45
Recall Alpha Data			
High Analytics			
Left hemisphere	1.11	.79	.79
Right hemisphere	.77	.50	.39
Low Analytics (Holistics)			
Left hemisphere	1.74	1.47	1.07
Right hemisphere	1.39	.96	.76

[a]Expressed in arbitrary units summed for both hemispheres.

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