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ABSTRACT

It is difficult to account for the real and easily measured differences in verbal competence. Differential psychologists investigate basic traits from which observed behavior is thought to be generated, but if thinking is viewed as a problem in information handling, research will more profitably focus on the relationship between behavior in handling problems of linguistic information processing and behavior on verbal aptitude tests. This will account for the way information processes vary between individuals. The recommended model of reading is based on a series of stages: decoding, active memory, sentence processing, and analysis using long-term memory. Differences in verbal competence have much to do with strictly mechanical components, particularly automatic structural processes such as decoding and short-term memory capacity, the ability to control attention, and the use of strategies, all of which are components of individual mental competence. The measures which would be expected to be important in information processing are roughly associated with general mental and verbal competence. (Tables and references are included.) (DF)

The Foundations of Verbal Comprehension

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Verbal ability, as tested by conventional aptitude tests, is associated with rapid access to memory in long term store, unusually good short term memory, the ability to control attention, and the ability to comprehend brief sentences rapidly. Differential background alone cannot account for the distribution of test scores.

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The Foundations of Verbal Comprehension[1]

Earl Hunt[2]

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It is currently fashionable to extoll the intuitive, wholistic, non-verbal process of the right hemisphere at the expense of the picky, verbal, serial processing of the left (Fincher 1976). The tyranny of language is deplored by those who profess to be humanists. This is amazing. Language is what makes us human, few of us have the spatial orientation of a hawk. The predominant mode of our thought is verbal, and if we are going to understand human cognition we must understand verbal thinking.

It is easy to measure verbal aptitude. By asking a few basic questions about vocabulary, grammar, and simple paragraph comprehension one can predict performance in a wide variety of situations. To illustrate, Table 1 shows the correlations between verbal aptitude scores, as measured by a conventional scholastic aptitude test, and grade point averages for a variety of majors at the University of Washington.

Tables 1, 2 about here

Outside academia similar relationships have been found. Table 2 shows the verbal aptitude scores achieved by a group of World War II aviation cadets, as a function of their subsequent civilian occupations. There are real, easily measured differences in verbal competence, and these differences have importance in our lives. Why these differences exist is very much an open question.

Differential psychologists search for the genesis of verbal competence by searching for a set of basic traits from which observed differences in behavior can be generated. Their methods of investigation are designed to reveal how many "basic" traits must be postulated, and to determine how these traits are related to other talents, such as spatial reasoning. I and my colleagues have taken a rather different approach, based upon our view of thinking as a problem in information handling. We have examined tasks that, on theoretical grounds, ought to be important in handling linguistic information processing problems, and asked how behavior on these tasks is related to performance on verbal aptitude tests. An important point is that we are not trying to "explain the test scores." Rather, we view the tests as convenient measures to assure that we obtain a range of verbal competencies in the populations we study. As will be shown, we are quite willing to use other measures of general intellectual competence. Our goal is to understand how information processing varies over individuals, not to predict the variance on a specific test.

It would be nice to believe that our approach will coalesce with more traditional research on aptitudes. After all, we are studying the same phenomena. There is no guarantee that this will happen. Indeed, I and my colleagues have begun to suspect that there are fundamental conceptual incompatabilities between the ways that differential psychologists and information processing psychologists view the problem of explaining individual differences (Hunt, MacLeod & Lansman, Note 1.). The explanations I shall propose for our findings complement rather than replace or amplify the explanations generated by conventional psychometric studies.

Theoretical Considerations

A basic assumption of information processing psychology is that language messages are handled in stages. The first is a decoding stage, in which arbitrary physical patterns are recognized as representations of concepts in the lexicon. The second stage is an active memory stage, in which the recognized lexical items are rearranged in memory until they form a coherent linguistic structure. The third is the sentence processing stage, in which the semantic meaning of the linguistic structure is extracted and incorporated into our knowledge of the current situation. In the fourth stage the current situation itself is analyzed with respect to information held in long term memory and, if appropriate, a response is chosen and emitted.

If people were literally computers, and if human languages could be analyzed by the techniques used to deal with computer languages such as FORTRAN or ALGOL, these stages would be executed in a strict sequence. People are not computers, and language analysis is not sequential. Nevertheless, the concept of stages is a useful one even when allowance is made for plentiful feedback between stages. I shall argue that individual differences appear at each of the stages of information processing and that they are important in determining verbal competence. My concrete evidence, though, will be confined to an analysis through the sentence processing level.

A listing of stages does not constitute a model. We must also consider the kind of control involved in analyzing language data. A substantial amount of information processing in the earlier stages of linguistic thought appears to take place in what Posner and Snyder (1975) have referred to as the automatic mode. This mode is simply defined, an automatic process takes place whether we wish it to or not, and it does not interfere with other ongoing processes. Recognition of the meaning of very familiar printed words is a good example. This process cannot be supressed even when it is advantageous to do so (Stroop, 1935). Once past the lexical stage, we begin to see more use of what Shiffrin and Schneider (1977) refer to as "veiled control processes"; processes that are not subject to conscious inspection, but that can be shown to draw upon attentional resources. The search processes psychologists have postulated to explain memory scanning experiments are frequently cited examples. Similar veiled processes occur when we are required to understand the meaning of very simple sentences, such as "The plus is above the star" (an example to which I shall return). We are not aware of how we analyze these sentences, but it can be shown that the analysis requires attentional resources.

A third level of attention allocation is represented by the conscious strategies people adopt to make sense out of language stimuli. An example of such a process is the strategy one might adopt for solving multiple choice test items. One could look at the question, select the best answer given the question, and then search for that answer among the alternatives provided. Another strategy is to read all the alternatives, and then examine the question to see which one fits best. Each strategy has different implications about attention allocation, and people are consciously aware of the strategies that they use.

More complex verbal problem-solving situations require still more complex skills for representing and attacking problems. To solve the mystery in a detective novel, for example, one must discover who had the motive, who had the means, and who had the opportunity. Some people may do this by constructing scenarios that they examine for plausability, perhaps through the use of visual or verbal imagery. Others may prefer the abstract logic of Sherlock Holmes. We know very little about individual differences at this level. Our lack of knowledge is a serious problem, for it biases our theorizing. There is no reason to believe that verbal performance is the result of a linear combination of component abilities, or that the same linear combination of components is applicable throughout the entire range of human verbal competence. Letter naming speed may be a good discriminator of the difference between the lower and average ranges of verbal ability, while the difference between the average newspaper reporter and a Pulitzer Prize winner may be more subtle. This must be kept in mind when we draw conclusions from the results of studies of "common garden variety" problem solvers.

In spite of this warning, we must concentrate on what we know. We have found that there are reliable individual differences in mechanistic processes of information handling within the population represented by university students, and within populations of somewhat lower ability. These differences appear to account for a substantial portion of the individual variation in verbal competence observed within these populations. The differences we have found do not appear to be associated with differential possession of knowledge about the language, but rather with differential ability to manipulate the symbols that comprise it.

Structural Processes

Decoding. Lexical analysis requires the decoding of arbitrary physical signals to connect them to conceptual units in a language. The sound /cat/ must be recognized as a referent for the animal. Posner and Mitchell's (1967) stimulus identification paradigm has proven to be useful in studying this process. In a stimulus identification study the subject is presented with a pair of highly overlearned stimuli, usually letters. The task is to state whether the two stimulu have the same name. First, consider the pair A-A. This is a physically identical (PI) pair, it would be possible to determine that these symbols had the same name even if you did not know what that name was. Next, consider the name identical (NI) pair A-a. In order to complete the identification task the names of these symbols must be retrieved from memory. A third possibility is that the pair is different (D), as in the case of A-B. If D and NI pairs are mixed it is necessary to retrieve the name of all letters in order to make the correct response.

Posner and Mitchell, and since them many others, found that it takes longer to make an NI than a PI response. A strictly serial model, in which physical identification is attempted first, and name identification attempted only if physical identification fails, justifies subtracting PI reaction time from NI reaction time in order to arrive at an estimate of the time required to retrieve the name of a symbol, surely an important part of verbal comprehension. For brevity, I shall refer to the NI-PI measure. A number of investigators have found that the NI-PI measure discriminates between persons whom one would think to have more or less verbal thinking ability. This data is summarized in Figure 1. The range of the measure is striking. A typical difference between NI and PI reaction times for a college student scoring in the upper quartile of a verbal aptitude test (a "high verbal" in subsequent remarks) is 65 milliseconds, whereas educable mental retardates show an NI-PI difference score of over 300 milliseconds (Hunt, 1978).

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Figure 1 about here

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In spite of the regular and interpretable picture presented by Figure 1, work with the stimulus identification paradigm in other settings has raised serious question about the accuracy of the serial model itself (Posner & Snyder, 1975). It appears more correct to assume that both the NI and PI tasks involve identification at the name level, followed by a binary choice and a motor response. The name retrieval process is more important in the NI task, because the names of two symbols must be retrieved, but the subtraction operation no longer has a simple theoretical interpretation. The resulting analysis becomes quite detailed, because the data analysis technique one uses to derive a measure of name retrieval depends upon the precise model on espouses for the task. (See Hunt et al., Note 1, for comments on the general problem.) Fortunately for those who wish merely to determine whether or not the name retrieval process is important in individual differences, the fact is that almost any reasonable choice of a response measure is satisfactory. The ratio of NI to PI reaction times increases as verbal competence decreases[3], and the correlation between measures of verbal competence and NI reaction time alone is generally in the .35 to .45 range (Lansman, Note 2; Jackson & McClelland, 1978).

If decoding is an important part of verbal competence one would expect to show a developmental trend for decoding, as verbal competence clearly grows with age. Table 3 presents some data gathered by Judith Warren as part of a doctoral dissertation now in progress. As can be seen, there is a strong developmental trend. Warren also found

Table 3 here

significant correlations between the NI-PI measure and WISC verbal IQ scores. Furthermore, there were significant sex differences in favor of girls, which is consistent with the general finding that girls outperform boys in verbal tasks (Maccoby & Jacklin, 1974).

Finally, if name retrieval is an important part of verbal comprehension one would expect it to have its maximum effect upon tests of reading. Jackson and McClelland (1978), using an extreme groups design, reported a correlation of .45 between NI alone and skill in reading in a college population, surely a group with a restricted range of reading comprehension. Our own results in studies of reading comprehension in a more general population confirms Jackson and McClelland's finding, and further suggests that the relation found may depend upon the level of verbal ability.

We can sum up these results by saying that there clearly is an association between verbal competence and the simple act of identifying the name of a symbol. This observation is of interest for two reasons; it provides a link between an important stage of verbal cognition, as identified by cognitive theorists, and individual differences as measured by conventional aptitude tests. Furthermore, the process does not seem to be an operation that would be influenced by differential knowledge possession. Most university students know the alphabet fairly well.

Holding information in active memory: In principle, one's memory should be involved in such simple cognitive acts as determining that a sentence is grammatical. There clearly are differences in short term memory capacity that are associated with language capacity, as shown by the many experiments that have related IQ to digit span. The correlation found, however, is often due to a radical drop in digit span in persons with very low general mental competence (Matarazzo, 1972). In order to consider the relation between primary memory and general mental competence in depth, we need to consider in more detail the components of the act of retaining information for a brief period of time.

Hunt, Lunneborg, and Lewis (1975) examined the active memory capacities of "high verbal" and "low verbal" college students, (i.e., students with low verbal scores for college students). We used a version of the Brown-Peterson short term memory paradigm, in which the subject was first shown four letters, then repeated aloud a string of digits, presented visually one at a time, and finally recalled the letters. Figure 2 shows recall performance as a function of the number of digits shadowed. The high verbal students appear to establish an initial

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Figure 2 about here

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advantage (perhaps due to rapid decoding) and then retain it in the face of the interfering material. This can be explained by the assumption that the high verbal students code information into recognized items more rapidly than do the low verbal students, but that they did not have an advantage in resisting interfering material.

In Hunt et al.'s study very short lists of items were used. What would happen if longer lists were used? Cohen and Sandberg (1977) report a large study of the relation between intelligence and the recall of supra-span lists by Swedish schoolchildren. Their subjects had to memorize lists of nine digits, which is well beyond the memory span for most grade school children. Using a probe recall procedure, Cohen and Sandberg estimated separately the children's ability to recall the first three digits presented (primacy), the middle three, or the last three (recency). They found that the correlations observed between recall and scholastic aptitude were due to the more competent children performing better on the recency portion of the curve. This is shown in Figure 3. Note that this is consistent with Hunt et al.'s results,

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Figure 3 here

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since the shorter lists that we used would be within the recency portion of the recall curve had we used the Cohen and Sandberg procedure.

The ability to recall strings of digits and letters is not particularly useful in most situations. We need to consider what advantages might be gained by having a good "recency" short term memory in intellectual tasks in general. We have found evidence for two types of advantage. Larger short term memories may increase the strategies that a person can use in a problem solving task, and performance on a short term memory task may indicate the attentional effort required to hold information in active memory. The less effort required to do this, the more capacity there is available for other tasks.

Suppose a person is asked to recall a list of some thirty or more words. Obviously errors will be made. Recall will be more accurate if the list is made up of items drawn from a relatively few semantic categories; say animals, vegetables, and minerals. In this case free recall displays the clustering phenomenon; the typical subject will recall items from one semantic category and then items from another (Bousfield, 1953). Hunt, Frost, and Lunneborg (1973) found, somewhat to our surprise, that high verbal students cluster less than low verbal students. The relevant portion of our data is shown in Table 4. This

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Table 4 here

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result was something of a puzzle to us, until Schwartz (Note 3) combined this result with the results on short term memory. Schwartz reasoned that high verbals could afford to not cluster part of a supra-span list because they could simply read out the last few items from active memory. If this were the case, then high verbals should show less clustering than low verbals on the first few items recalled, but would show progressively more clustering as recall progressed, because the later recalled items would be retrieved from long term rather than from active memory. Table 4 also shows Schwart's data, it is clear that his hypothesis was borne out. Because of their greater short term memory capacity, the high verbals had a strategy available that the low verbals could not use.

The fact that students with high verbal aptitude scores have larger active memories need not imply that they have larger skulls. An alternative formulation of active memory capacity focuses upon the allocation of attention. Lansman (1978) combined the Atkinson and Shiffrin (1968) continuous paired associates procedure with the secondary task methodology (Norman & Bobrow, 1975) to measure the effort devoted to memorizing information. Her subjects had to respond to a light by pressing a button, while keeping track of the changing state of 0 variables (no memory load), 2 variables (light memory load), or 6 variables (heavy memory load). There was a substantial increase in reaction times to the light signal from the no memory load to the light load condition, even though subjects made virtually no errors under the light load. Furthermore, the amount of the increase in the light load condition was a predictor of the number of errors that would be made in the high load condition. This demonstrates the fact that active memory maintenance is an attention demanding act, and that there are individual differences in the ability to bring attentional resources to bear on it. Since memory load is a component, but only one component, of tasks such as sentence parsing or the solving of simple arithmetic problems (Hitch, 1978), and since these tasks are also attention demanding, it is clear that it would be advantageous to be able to devote less capacity to memory and more to problem solving in many situations. But is it the case that the verbally competent simply have a greater attentional capacity, or are they more able to focus their resources?

Attention Allocation

Posner and Boies (1971) distinguished three separate aspects of attention; general arousal, the capacity to restrict attention to task relevant cues, and the ability to switch attention from one task to another. All, one, or two of these components might vary with general verbal aptitude. An unpublished experiment by Steven Poltrock and myself provided some relevant data. Sixty high school students participated in a series of tasks designed to measure different aspects of the ability to control attention.

In order to measure general attention level we used a simple two-choice reaction time task, in which the subject faced a screen on which a light appeared. The light could appear at either of two locations, and the subject's task was to press a switch immediately under the light location. Thus this task provides a measure of general alertness, plus a component due to choice reaction time under conditions of high stimulus-response compatability.[4] Measuring selective attention presented a more difficult problem, as one could imagine different forms of selective attention, depending upon the nature of the stimulus to be attended to and the nature of the interfering stimuli. We decided to average performance on three separate tasks thought to require selective attention. These were:

(1) The Stroop (1935) effect; measured by the time required to name the ink in which color names were printed minus the time required to name the color of the ink in which asterisks were printed.

(2) The time required to read aloud a randomly ordered sequence of words minus the time required to read the same words in a coherent text. The reading of random words requires that the subjects suppress the normal tendency to scan ahead when reading aloud, in order to pick up cues concerning voice and intonation.

(3) Shadowing in the presence of dichotic interference. Mixed lists of words and digits were presented to each ear. The task was to report the digits presented to one of the ears, the measure of interference was the number of intrusions, defined as the report of a digit presented to the wrong ear.

In order to obtain an overall measure of sensitivity to selective attention the scores in these three tasks were standardized and added.

Finally, we required a measure of attention switching. Here, fortunately, we could benefit from previous work (Gopher & Kahneman, 1971; Kahneman, Ben-Ishai, & Lotan, 1973) that had shown substantial individual differences in a variant of the dichotic listening paradigm. As subjects were shadowing one ear they would be signaled to switch to the other ear. On control trials they simply received a signal indicating that they should continue to monitor the ear they were now shadowing. Our measure of speed of attention reallocation was the number of digits correctly reported immediately following a switch.

There was no correlation ($r = -.06$) between the simple reaction time task and verbal aptitude. On the other hand, there were significant correlations between verbal aptitude and measures of both selective attention and attention switching. These correlations are shown in Table 5. In addition to the significant first order correlations, both selective attention and attention switching have significant partial correlations with verbal aptitude when the other attention measure is

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Table 5 about here

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controlled.

This experiment is at best a start toward the study of attentional factors in intellectual competence. While a great deal of work needs to be done, the result is consistent with the idea that the control of attention is important. This becomes of interest when we consider an explicitly verbal task that requires attention allocation, the comprehension of sentences.

Sentence Comprehension

The experiments to be considered in this section deal with verification of simple linguistic descriptions of a simple world. The task was developed by Clark and Chase (1972), who used sentences of the form PLUS IS ABOVE STAR or PLUS IS NOT BELOW STAR and pictures of the form ($\stackrel{+}{*}$) or ($\stackrel{*}{+}$). In the "sentence first" version of the paradigm the subject is first shown a sentence, then a picture, and must indicate whether or not the sentence accurately described the picture. The dependent variable is <u>verification reaction time</u>, the time between display of the picture and the subject's response. An alternative procedure involves presenting a large number of pictures and sentences in paper and pencil form, and asking how many the subject can verify in a fixed time. There is a correlation of .70 between the two procedures (Lansman, Note 2).

The sentence verification task has a number of features that recommend it as a measure of verbal information processing. On the face of it, the task is impossible unless one knows the meaning of words, but on the other hand the words used are so common that it can be presumed that they are in the vocabulary of every junior high school graduate. We are confident that any variations in verification time due to individual differences in word identification will be due to decoding difference rather than being due to differences in vocabulary. It is an attention demanding task, as can be shown by an analysis using the secondary task methodology (Hunt & MacLeod, Note 4), and the attention demands are closely tied to the complexity of the comparison process. Verification reaction times increase for negative compared to affirmative sentences, and false sentences generally take longer to reject than true sentences do to confirm (Clark & Chase, 1972). Given these facts, it is not surprising to find that people with high verbal aptitude scores are more rapid at sentence verification (Baddeley, 1968; Hunt, Lunnenborg & Lewis, 1975; Lansman, Note 2). The correlation between sentence verification reaction time and verbal aptitude measures is generally in the .35-.55 range. Lansman (1978) found that this correlation can be substantially improved by introducing choice reaction time as a covariate. Note that this is a reasonable thing to do because the final motor response is a choice of making the "true" or "false" response. When simple choice reaction time (measured by a procedure similar to that used by Poltrock & Hunt) was "held constant," the partial correlation between sentence verification time and a vocabulary test was .73. A similar correlation was found with a reading comprehension test. As the vocabulary and comprehension measures in Lansman's study referred to tests taken as much as three years before the experiment itself, this correlation approaches the test-retest reliability of the psychometric measure. Furthermore, on the face of things there is no reason why someone who knows many words should also be quick at verifying sentences consisting of simple words.

These results are encouraging to those who seek a rapid measure of verbal competence that is not bound to knowledge. I shall now report some studies that show how much strategies can influence information processing. A slight change in procedure, from the simultaneous presentation condition used by Baddeley and by Lansman to the sentence first procedure used by Clark and Chase, introduces a new and significant source of variance. In the sentence first procedure the subject can choose different strategies, and this choice can play havoc with an analysis of the traits that underlie performance.

To recall the task briefly, in the "sentence first" procedure the subject is shown the sentence, given a chance to read and comprehend it, and then shown the picture. MacLeod, Hunt, and Mathews (1978) found that when this was done some people read the sentence, memorized it, described the picture to themselves when it was shown, and then compared the descriptions. Let us call these people "verbal problem solvers." Another group of subjects, whom I shall call "visual problem solvers," used the sentence as a cue to visualize the expected picture, and then compared the actual picture to an image of its expectation. Individual performance of the verbal problem solvers was well predicted by a test of verbal aptitude, while performance of the visual problem solvers was well predicted by a test of spatial aptitude. This statement, however, does not really capture the contrast between the data of the two groups who, it will be remembered, were the same stimuli. To bring the distinction out more clearly, Figure 4 plots the mean verification reaction time for each group of subjects as a function of the linguistic complexity of the verification task, calculated by applying Carpenter and Just's (1975) linguistic comparison model to the task.

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Figure 4 here

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The close fit of this group to the Carpenter and Just model is not surprising. MacLeod _et al_.'s method of definition of groups ensured that there would be one such group. What is interesting is the complete lack of fit of the second group. A result that was not dictated by the analytical procedures. Further, the "visual" group's data could not be fit by _any_ reasonable linguistic model, as this data shows no effect of negation, which many studies have shown to be a powerful psycholinguistic variable.

For one who seeks stable predictors of performance this result is a minor disaster. We have shown that choice of strategy may determine correlational patterns, a situation that is anathema to orderly psychometric models. In theory, predictive power might be restored by using a person's choice of strategy itself as a marker in making predictions. Unfortunately this will not work, either, for one can change an individual's pattern of data simply by requesting that the subject use an alternative strategy. Figure 5 shows some data from one of the subjects in a second (yet unpublished) study by Mathews, MacLeod, and myself. This subject was first allowed to choose a strategy, and evidently chose a verbal one. Subsequently he was asked to use avisual strategy, and then a verbal one. Similar switches can be produced in the behavior of

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Figure 5 here

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subjects who initially begin with visual strategies. If qualitative changes of behavior can so easily be produced in this straightforward task, how many strategies are there for understanding _War and Peace_?

Concluding Comments

It seems clear that there are strictly mechanical components to individual differences in verbal competence. I have argued that these differences lie in three major areas; automatic, structural processes such as decoding and short term memory capacity, the ability to control attention, and the use of strategies. While the automatic processes are reasonably stable over time and situation, it is clear that the attentional processes and strategy choices are liable. Are these processes reasonably considered part of intelligence?

They certainly are components of individual mental competence. Given that, who needs the concept of intelligence? I believe that we ought to drop the notion of intelligence as a trait, or even as a space of traits, when we are trying to understand intellectual performance. Traits are statistical abstractions, and do not refer to any physical processes inside the head. If our theories of cognition are correct (admitting a big "if"), parameter estimate of information processing stages and structures may be closer to measuring real things than are the psychometric procedures for trait estimation. When mental competence is to be studied as a phenomena to be explained, information processing measures provide more useful dependent measures. For example, it seems to me that studying the genetic correlates of performance on an omnibus "IQ" measure has little point, but that studying the genetic correlates of symbol decoding or short term memory capacity is reasonable. It seems equally reasonable to speak of two individuals as being comparable in their normal mental competence, and then adding that one is more prone than the other to deterioration in attentional control mechanisms due to some pathological condition, such as alcohol intoxication. Is one "less intelligent" than the other? The question does not make sense.

The question changes somewhat when mental measurement is to be used as an independent variable in a predictive situation. At times we legitimately make predictions about abstract concepts on a mass basis, e.g., predictions about occupational success as a function of mental competence. In such cases we are predicting from one statistical abstraction to another, and the traditional psychometric methods are quite appropriate. In other cases, though, we may desire absolute rather than relative prediction. This is particularly likely to occur when we are interested in the performance of identifiable individuals on specific tasks. To be pragmatic, will Astronaut Smith be able to land the mars probe within x meters of the target point? In such situations the absolute, information processing approach to mental capacity may be made more useful than the relativistic approach of psychometrics.

In spite of the fact that this article presents a number of correlation coefficients, I stress again that we are not interested in explaining the intelligence test...we simply use these tests as rough and ready measures of general competence. We have shown that the measures one would expect to be important in information processing are roughly associated with general competence. If the correlations are not higher this may be at least as much the fault of the aptitude tests as it is of the information processing measures. In our future work I and my colleagues plan to go beyond these correlational studies, to examine how the information processing measures covary with each other, and how they change as individuals and as ecologically valid variables in individual life change. We will be looking at changes in individuals over age, time of day, relationship, and drug state. While we may never compute another correlation coefficient between an information processing measure and a psychometric trait (although I suspect that we will), we will still be developing a theory of individual differences. This theory is intended to provide a complement to trait theories. It certainly will neither expand nor replace them.

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Notes

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3. This measure cannot be compared across experiments, as motor reaction time will be markedly influenced by apparatus variables.

4. A warning signal always preceeded the choice signal in this experiment. In retrospect, we ought to have compared conditions with and without the warning signal, in order to measure the speed with which the subject could alert him/her self to the stimulus situation.

Table 1

Anthropology	.34	English	.30	Scandanavia Lang.	.34
Astronomy	.35	History	.35	Nursing	.41
Chemistry	.19	Psychology	.27	Forestry	.34
Economics	.30	Sociology	.31	Mathematics	.14

Correlations between verbal aptitude scores (Washington Pre-college test - verbal composite) and game point average in selected major. (Source: U. of Washington Records)

Table 2

Accountant	.28
Chemical Engineer	1.06
Engine Mechanic	- .28
Insurance Salesman	.05
Lawyer	.39
Physician	.59
Social Worker	- .08
Vehicular Mechanic	- .72

Mean standard scores of cadets on Air Force Test Battery (general intelligence) as a function of later occupation. Data from Thorndike and Hagen, 1959.

Table 3

Age	NI	PI	Difference
13	1.91	1.74	.17
10	2.07	1.85	.21
7	2.50	2.21	.29

NI and PI reaction times in seconds
for children at various ages

Table 4

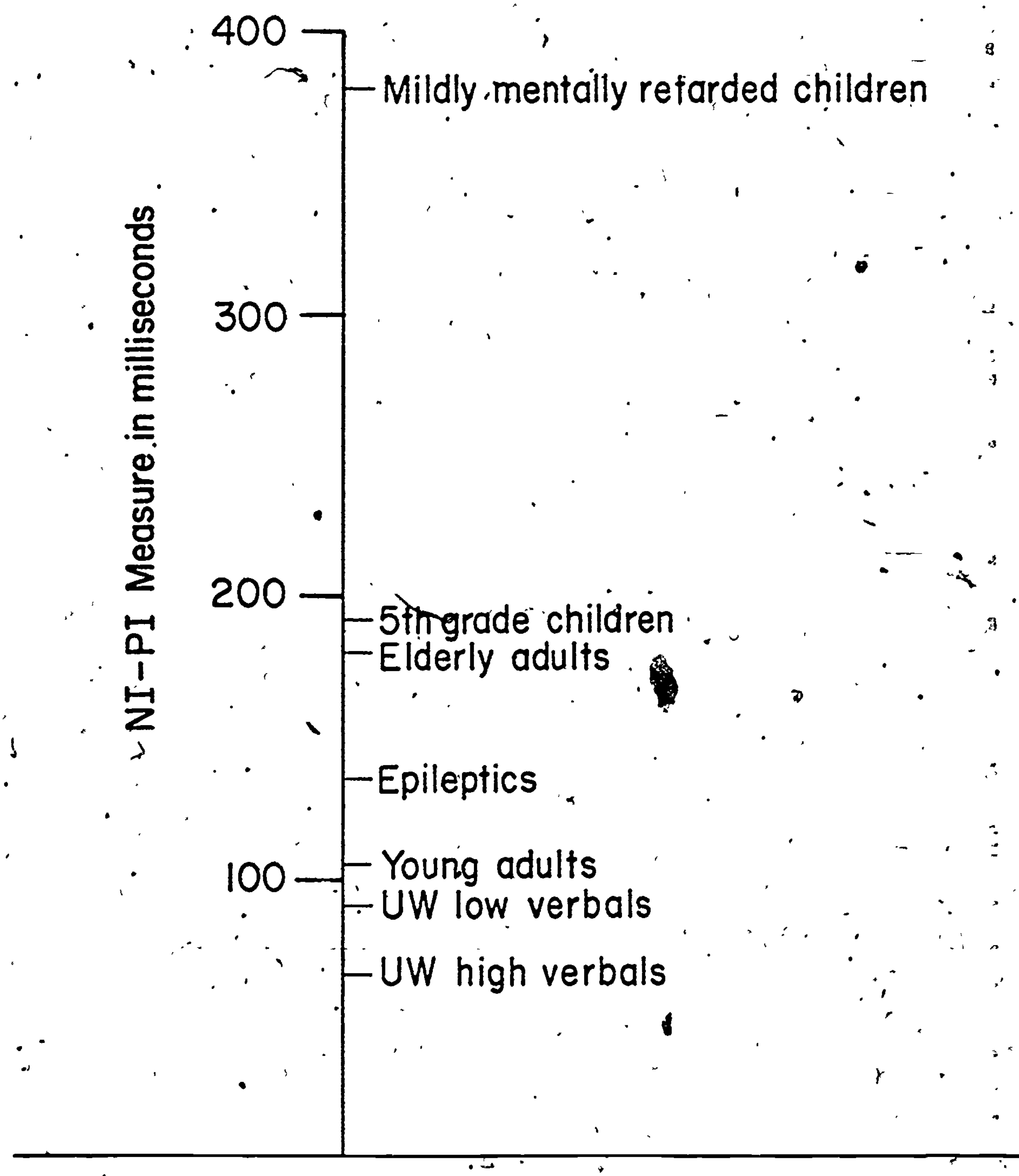
	Hunt et al. Full List	Schwartz: Data by Order of Recall 1st 1/3	2nd 1/3	3rd 1/3
High Verbal	.68	.29	.81	.79
Low Verbal	.84	.71	.82	.84

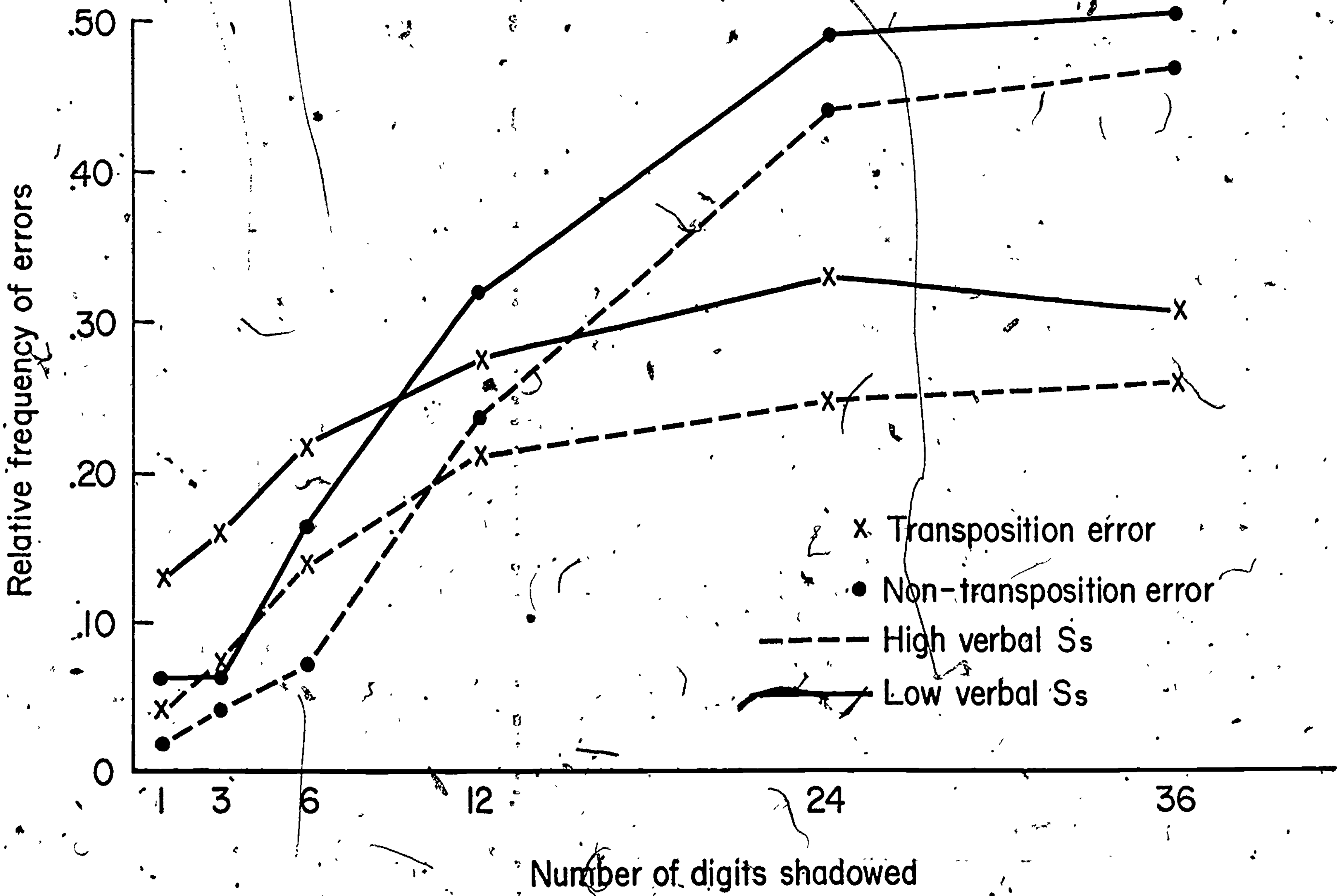
Clustering index by recall order and verbal aptitude. Items presented in random order.

Table 5

	Attention Switching	Verbal Aptitude
Selective attention	.30	.40
Attention switching	---	.48

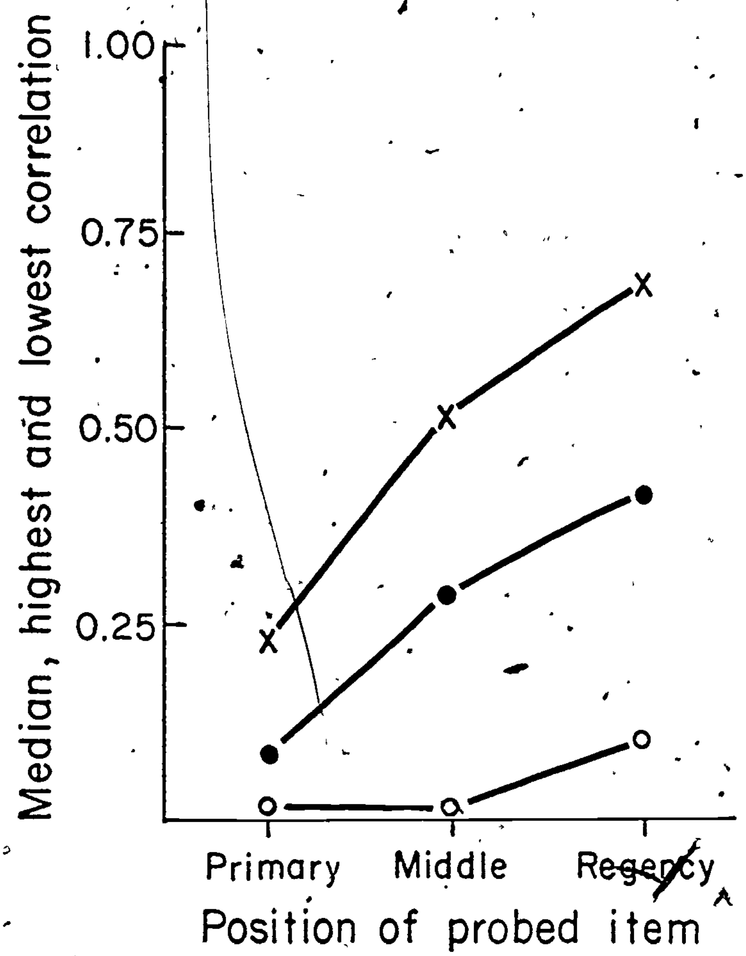
Correlations between verbal aptitude and attention measures.


NI-PI Measure in milliseconds
400
300
200
100
Mildly mentally retarded children
5th grade children
Elderly adults
Epileptics
Young adults
UW low verbals
UW high verbals

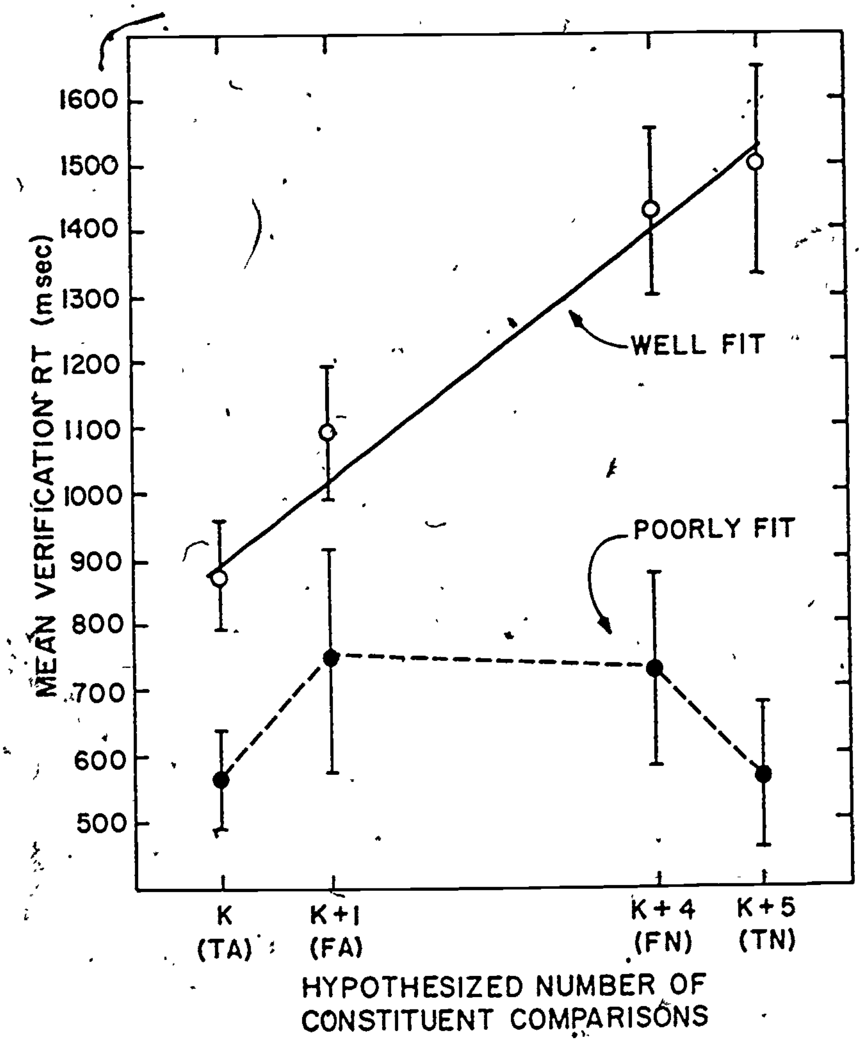


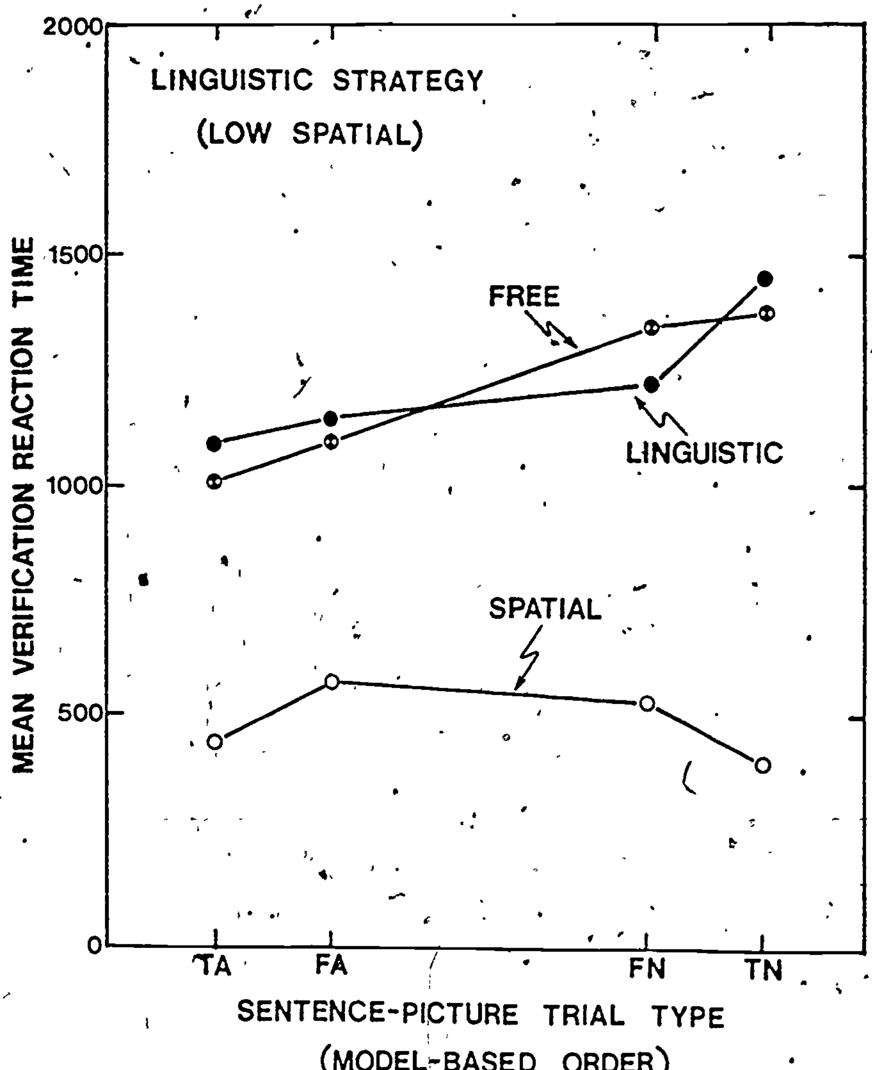
Relative frequency of errors
.50
.40
.30
.20
.10
0
1
3
6
12
24
36
Number of digits shadowed
x Transposition error
● Non-transposition error
High verbal Ss
Low verbal Ss

33



Representative results for correlation between STM recall and aptitude: From Cohen and Sandberg, 1977


1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
MEAN VERIFICATION RT (msec)
WELL FIT
POORLY FIT
K
(TA)
K+1
(FA)
K+4
(FN)
K+5
(TN)
HYPOTHESIZED NUMBER OF
CONSTITUENT COMPARISONS


LINGUISTIC STRATEGY
(LOW SPATIAL)
MEAN VERIFICATION REACTION TIME
2000
1500
1000
500
0
FREE
LINGUISTIC
SPATIAL
TA
FA
FN
TN
SENTENCE-PICTURE TRIAL TYPE
(MODEL-BASED ORDER)