Grammar and the Recall of Chains of Verbal Responses

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Recent research in the area of verbal behavior has turned to the examination of grammatical models for the explanation of the emission of and response to (understanding of) complex chains of verbal responses. In our laboratory, we found it useful to describe the statistical approximations to English, generated by Miller and Selfridge (1950), in terms of variations in both grammatical and content relations (Salzinger, Portnoy and Feldman, 1962). Chomsky (1957) has claimed that an approach to grammar in terms of frequency of single words and frequency of their combinations is inadequate and he has promulgated a transformation grammar which psychologists such as George Miller (1962) have used to investigate the psychological aspects of grammar.

The validity of the transformation model of grammar -- namely, that there is a set of rules which allows the subject to change or transform the simplest kind of sentence, the kernel, into the more complicated structures -- is of course an empirical problem. The simple declarative affirmative sentence in the active mood -"The boy threw the ball"-- would be an example of a kernel, and the passive negative query -- "Wasn't the ball thrown by the boy?" -- an example of a complicated structure. Miller (1962) and Mehler (1963) suggest that memory for complex structures depends on the coding of the kernel sentence plus some indication of what transformation must be performed to rearrange the words into their correct and more complex order. It follows from this that when subjects (Ss) are given kernel sentences to memorize, they should make fewer errors than when given more complicated structures, and this is in fact reported (Mehler, 1963). Unfortunately, the prompting method of recall used by Mehler, which consists of supplying S with discriminative stimuli for the lexical words and not for the function words which serve to differentiate the structures of the sentences, would be most helpful to kernel sentences, and might therefore have produced an artifact in his experiment. Furthermore, the different number of words in the various structures -- from 6 for the kernel to 8 in the passive negative query (PNQ) -- should have been controlled to assure that the smaller number of words alone or in interaction with the prompting procedure or in interaction with the differences in structure, could not explain the differences in memory between the kernel and the other sentences.
In view of these somewhat equivocal results and to test the theory, it seemed reasonable to investigate the degree to which sentences of different grammatical structures can be recalled. Since Chomsky (1957) has claimed independence of grammar and meaning, it was decided to use a technique recently employed by Epstein (1961), namely, nonsense syllables with bound morphemes and function words so arranged as to provide the discriminative stimuli for different sentence structures. Two structures were employed which were described as most different in Miller's (1962) paper, i.e., the active affirmative declarative sentence (kernel) vs. the passive negative query. Furthermore, the same number of word units was employed in both structures to eliminate the possible artifact of Mehler's experiment. Finally, by using a condition in which the units were presented in non-sentence order, we were able to measure the influence of grammatical structure by itself on memory and thus to replicate and extend (by including an additional structure) the experiment first done by Epstein (1961).

Method

Materials. Two grammatical types of 10-unit "sentences," each consisting of two different sets of function words and nonsense syllables, were constructed. One grammatical structure was a simple declarative sentence (D) and the other a passive negative query (PNQ). The nonsense syllables selected for the experiment had association values ranging from 73 to 89% (Glaze, 1928); disyllables used varied between 1.26 and 1.28 in meaningfulness (Noble, 1952). The required characteristics of English syntax were simulated by adding the prefix "be" and "de" to indicate verbs, and the suffixes "s" for nouns, "y" and "er" for adjectives, "ly" for adverbs, and "ing" for verbs, as well as by using function words. The frequency of occurrence of successive bigrams and trigrams of the disyllables (Underwood and Schulz, 1960) was approximately equated for the two sentence sets (a and b in Table 1). Inspection of Table 1 shows that the same two basic sets of units were employed in all the word series. However, the following exceptions were made to keep number of word units the same for the two grammatical sentences: the function word "and" was used in the D sentence to match the required function word "by" in the PNQ sentence, the verb ending "ing" in D was matched by the ending "ed," and the word "were" in D was matched by the word "weren't" in PNQ. The first word in each of the four sentences was capitalized; the two D sentences ended with a period; the two PNQ sentences ended with a question mark. The order of the words in each of the sentences was randomized according to the same random order to produce four unstructured series. Both capitalization and punctuation were omitted from these random series.

Insert Table 1 about here

The verbal material was prepared for presentation on a Lafayette memory drum (Model 303) by both a serial and a whole method. For the whole method of presentation, each series was typed in a single horizontal line across a separate 8.5" X 11" sheet of white paper. The series was centered on the page and one space separated successive words. For the serial method of presentation, the words of a given series were typed successively in the middle of the page with the second word centered under the first and so on. Two lines were skipped between successive words and any punctuation immediately followed the last word.
A random series of ten single digits was constructed with the aid of a table of random numbers within the restrictions that all digits from 1 to 9 inclusive be used and that the same digit appear in both the second and seventh positions to follow the repetitions occurring in the D sentences. This series of digits also was prepared for both the serial and whole methods of presentation. Four spaces occurred between successive digits in the whole method.

Subjects (Ss). Eighty undergraduate and graduate students whose native language was English were employed. Their ages ranged from 18 to 28 years.

Procedure. Ss were tested individually and paid $1.50 an hour for participating. Ss were randomly assigned to one of 16 experimental conditions which consisted of all combinations of the variables listed below, except that a given S received both sets (a and b) of stimulus material under the exact same conditions. The variables combined were: grammatical structure (D vs. PNQ); word order (sentence order vs. random arrangement of words); stage of learning (first vs. second presentation of a or b); method of stimulus presentation (entire series at once (whole) vs. one unit at a time (serial)). For purposes of analysis, errors were counted separately for nonsense syllables and for function words, thus giving rise to a fifth main factor used in the analysis of variance. All Ss were presented with the series of numbers first: the entire series or one unit at a time in agreement with the presentation conditions of the material which followed.

Ss were given the following instructions for the whole method of presentation, modelled after Epstein (1961):

"I am going to show you a series of numbers for 10 seconds. Shortly after I say 'ready', these numbers will appear in the window of the machine before you. Your task is to learn the numbers in the order in which they are arranged. Distribute your attention evenly among the items so that you can learn all of them. When the 10 seconds are over, you will have up to 30 seconds in which to write down the numbers in their correct order. You are to write them in the blanks on the sheet of paper before you in the order in which they were shown to you. Please put only one number in each blank. Then hand me the paper as soon as you are finished. We will repeat this procedure until you write the series correctly on three successive trials. Guess when you are not certain of any given item. Do you have any questions? I will be unable to answer any questions once we start this procedure."

Ss in the serial presentation condition were given substantially the same instructions as above except that they were told the numbers would appear successively in the window of the machine. The single digits appeared at a rate of 1 per second.

In both the serial and whole methods the procedure was repeated until S wrote the digits correctly on three successive trials. Immediately after a trial, E checked the record. To be correct, all the digits had to appear in correct order. S was given no knowledge of results until after the third successive correct trial, at which point E said, "good" and asked if S had any questions about the procedure. When it was ascertained that S understood the procedure, E proceeded to the presentation of the first series of nonsense and regular words.
Ss receiving the grammatically structured series (D or PNQ) by the whole method were told:

"Now in the same manner, I am going to show you a sentence composed of both nonsense and regular words for 10 seconds. Again, try to learn all the words in the order in which they are arranged and distribute your attention evenly among the items. After the 10 seconds you will be given up to 30 seconds to write down the words in their correct order in the blanks provided. Remember to put only one word in each blank and to give me the paper as soon as you are finished. Again we will repeat this procedure until you write the sentence correctly on three successive trials. Please guess when you are not certain of a word."

Ss administered the same grammatically structured series as above by the serial method were given substantially the same instructions except that they were told that the words would appear successively in the window.

Ss given the random series (whole or serial) received instructions like those above, except for the following:

"These words were originally arranged to make up a sentence. But I am going to present them to you in scrambled order so that they no longer read like a sentence."

Ss were still required to learn the words in the order in which they were presented. Words were counted as "correct" when they were written in correct order and spelled the same as the stimuli. For three Ss who made the same single spelling error for 10 successive trials, the experiment was terminated at that point, and the data included in this study. One S had the PNQ sentence (Set a) presented serially, one the D sentence (Set b) presented serially, and the third had the D sentence (Set b) presented whole.

After each S learned the first word series, E said, "good" and immediately proceeded to the second word series following the same procedure.

Results and Discussion

Recall of numbers. Statistical analysis showed that it took Ss almost twice as many trials to reach a criterion of 1 10-unit sequence correctly recalled when using the serial method than when using the whole method (t = 5.19, p < .001). This difference remained when comparing whole vs. serial on a criterion of two and three successively correct recalls (p < .001). It indicates that presentation of an entire sequence of units rather than one item at a time will result in faster learning even when the sequence is not arranged according to some underlying order. This difference is probably due to the fact that S can distribute his attention in such a way that combinations more difficult to learn get more practice. Furthermore, S can arrange the items in larger units when all are exposed at once.

Recall of nonsense syllables. The recall data were converted into two basic scores: number of errors per function word and number of errors per nonsense syllable. A five-way analysis of variance was then performed on these basic scores. Table 2 shows the mean error scores for the contrasting conditions
of each variable, as well as the level of significance, for the criterion of 3 successive correct recalls. Analysis of variance to a criterion of 1 correct recall shows substantially the same results, the exception being that only for the lower criterion is there a significantly greater number of errors for the PNQ than for the D structure (p < .05).

**Grammatical structure.** The difference in memory due to grammatical structure is at best equivocal. It is interesting to note in this respect that the Grammatical Structure-Stage of Learning interaction (Table 4) shows a larger number of errors in the PNQ structure than in the D structure for the first presentation only, i.e., at the beginning of learning only. These results suggest that earlier relative unfamiliarity with the PNQ structure is simply overcome by presenting S with that structure. In terms of learning theory, the successive words of the PNQ sentences may be posited to evoke other than the called for words at the beginning of learning because of the higher frequency of occurrence of these competing responses. If Ss did in fact commit the kernel and the transformation rule to memory separately then one should find more errors for the PNQ than for the D sentence for both presentations.

If we accept the equivocal difference between grammatical structures as real and go on to further inspection of the conditions under which grammatical structure affects recall, we see (Table 3) that PNQ gives rise to more errors than D only in serial presentation. Following Epstein's reasoning (1962), we should expect such a difference only for whole presentation, since only it would allow S to learn the underlying structure. Inspection of Table 8 shows still another reason for rejecting the notion of a plan or underlying structure since the difference between D and PNQ stems almost wholly from the comparison of the random arrangements of D and PNQ under serial conditions of presentation. The reversal under whole conditions of presentation clarifies the interaction of Table 3; apparently, whole presentation allows S so to distribute his attention over the items as to compensate for the differences in difficulty. It would seem most reasonable to conclude that the grammatical structures do not produce differences as structures but rather in terms of the frequency of occurrence of their words or combinations of words. The fact that the words of the PNQ structure produce a large number of errors when in random arrangement (Table 8) raises the possibility that they are generally combined in fewer different ways than the words of the D structure. In other words, we are suggesting that the random arrangement of the PNQ structure results in a relatively greater number of chunks (Miller, 1956) or units (Salzinger, 1962) than the randomly arranged D words, since the words in the PNQ sentences are less frequently used in other combinations. It is certainly most difficult to explain this result in terms of transformation grammar, which presumably is irrelevant to random (ungrammatical) sequences.

**Word order.** Our results are in agreement with Epstein's findings (1961, 1962) that words in random order produce a greater number of errors than the same words in sentence form (Table 2). It is interesting to note, however, that here, as for the grammatical structure variable, the difference due to
word order is evident only early in learning (p < .005, see Table 5).

Table 7 indicates that the difference in recall due to word order does not manifest itself at all for nonsense syllables when they are presented serially. On the other hand, for function words the difference is even larger for serial than for whole method of presentation, suggesting that for function words the immediate associations are more important than they are for the nonsense syllables. The mere separate (serial) presentation, even in sentence form, is sufficient to give rise to less recall for the nonsense syllables so that randomization does not lead to further decrement. In other words, the nonsense syllables may depend more upon long-range associations between words. Thus, Epstein's failure to find a difference in memory due to word order when using the serial method may be largely ascribed to the difficulty in recalling nonsense syllables under these conditions. Inspection of Table 8 shows that this variable is also involved in the triple interaction with grammatical structure and method of stimulus presentation. The interaction roughly corroborates Epstein's finding (1962) that the difference due to grammatical structure manifests itself when using the whole but not the serial method of presentation, as long as we look at the D sentence only. His conclusion is not warranted, however, for the PNQ sentence which shows the difference due to grammatical structure to be at least as great for the serial as for the whole method of presentation. It might be noted here that the serial method as used in this experiment differs in two respects from Epstein's study. First, Ss were told that they would be presented words from a sentence in sentence or in random order; Epstein's Ss were not. Secondly, Ss responded in the same way for the whole and serial presentation methods, i.e., by writing out the entire sentence after seeing all stimuli one at a time, while Epstein's Ss followed the usual anticipatory serial learning instructions. Our findings therefore suggest that Epstein's conclusion, that "chains of immediate probabilistic associations within the structured sentences" cannot be used to explain the difference due to grammatical structure, may have been premature. As to the closeness of error score in the serial presentation of D and PNQ sentences, we have already suggested that the D sentence words probably give rise to more familiarity both in the higher frequency of occurrence of single words and their various combinations.

Stage of learning. Table 2 shows a clear difference (p < .005) between number of errors made for the first and second series of words learned. Furthermore, we have already indicated how the stage of learning interacts with word order (Table 5) and with grammatical structure (Table 4) -- i.e., the first presentation consistently gives rise to larger error scores than the second presentation, and the second presentation consistently washes out the effect of the aforementioned variables as well as the apparent advantage of the whole over the serial method of presentation (Table 6).

Stage of learning is of course a frequency of occurrence variable and the results suggest its importance for explaining differences in ability to recall different grammatical structures. Since the D structure most likely occurs quite frequently in verbal behavior (text as well as speech) to which the average S is exposed, one would expect more positive transfer to it than to the PNQ structure which occurs less frequently.
Method of stimulus presentation. Table 2 shows that the whole method of presentation is superior to the serial method but Table 6 indicates (as mentioned above) that this difference occurs only for the first presentation. Furthermore, Table 3 shows that the difference between the two methods of presentation is more marked for the PNQ structure than for the D structure. Finally, the method of presentation variable is involved in two significant triple interactions: Table 7 shows, as already indicated, that the method of presentation is more important for distinguishing recall of nonsense syllables in sentence order and function words in random arrangement than for the other two combinations. We shall discuss the implications of this relationship below. Table 8 shows that the serial method of presentation gives rise to larger error scores than the whole method except for the random arrangement of the D structure, when a slightly larger error score is found for the whole than for the serial method of presentation. This interaction indicates that, for the D structure, exposing the whole series of words in random arrangement gives rise to approximately the same number of errors as exposing them one at a time, while for the PNQ structure serial presentation further increases error scores even after it is randomized. These results have already been explained when discussing differences due to grammatical structure.

Word type. Table 2 shows that nonsense syllables are almost three times more difficult to memorize than function words. This difference is involved in a triple interaction with method of stimulus presentation and word order (Table 7). Although the nonsense syllables give rise to higher error scores than do function words for all conditions, the difference is greater in sentences than in random arrangements. Although the function words are easier to recall than nonsense syllables because of their higher frequency of occurrence, they also show more dependence upon context than the nonsense syllables. The relatively greater dependence of function words upon context is in agreement with a recent experiment by Glanzer (1962), who has maintained that function words are incomplete units but can be made complete by embedding them among nonsense syllables which alone are also incomplete units. This experiment showed that function words can be made part of a complete unit by embedding them in a nonsense syllable sentence (for more extensive discussion of the problem of unit see Salzinger, 1962).

General discussion. Thus, in general we are led to the conclusion that Miller's notion (1962), that a S commits a complex sentence to memory by storing its kernel plus a footnote concerning the selection of the appropriate transformation, is not corroborated by the data of this experiment. Notions of frequency of occurrence (a basic variable in behavior theory) of the words or their combinations contained in the different structures appear to agree more with our findings. The importance of the frequency of occurrence variable continues to be demonstrated in current research. A recent example was given by Baddeley (1964) who showed that series of nonsense syllables can be learned more rapidly if the last letter of each syllable and the first of the subsequent one are "compatible" than when they are not. Compatibility is defined merely in terms of the number of letters required before a S will guess the next letter -- a simple frequency of occurrence relationship.

It might also be pointed out that other experimenters have suggested alternative formulations to explain the influence of grammatical variables in verbal behavior. Braine (1963a, 1963b) has suggested that people acquiring a language learn the location of units within sentences and associations between
pairs of words. Jenkins and Palermo (1964) suggest sequence and class of words as important aspects of language learning. Finally, Salzinger (1959) and later Staats (1961) pointed out the importance of the concept of response class in operant conditioning, i.e., what response members do in fact combine to form a response class, and in a later paper Salzinger (1962) showed the importance of unit size for understanding the properties of speech. In summary, a number of investigators have suggested concepts derived from learning theory which could explain at least those properties of grammar currently being investigated. In view of the equivocal nature of the behavioral evidence for a transformation grammar, it would seem advisable at this point to further investigate the application of these concepts to simple structures and then determine what concepts, if any, must be added to handle more complex structures. Such work has already begun in experiments by Martin and Jones (in press) and Martin, Davidson, and Williams (in press) and in our own laboratory by Salzinger, Salzinger, and Hobson (in preparation).

**Summary**

The validity of the transformation grammar for explaining differences in recall of different classes of verbal responses was tested by having 80 Ss learn, in order, one of two different grammatically structured series of 10 nonsense syllables and function words. The two grammatical structures, each represented by two different sets of nonsense syllables, were a simple declarative sentence (D) and a passive negative query (PNQ). They were presented in serial order (one word at a time) or whole (all words at once along a single line) in sentence order or at random. Analysis of the error data was carried out over these variables as well as over stage of learning (first vs. second presentation) and word type (function word vs. nonsense syllable). The analysis to a criterion of 3 correct recalls indicated that all the main variables gave rise to significant differences except for grammatical structure. Function words were more easily recalled than nonsense content words; structured sentences were superior to randomly ordered sentences; whole presentation gave rise to fewer errors than serial presentation; and recall for the second sentence (containing different nonsense syllables but identical orderings as the first) was superior to that of the first. Interactions showed that differences between sentence and random order, between D and PNQ, and between whole and serial learning were markedly reduced from the first to the second presentation. Function words were found to depend more on contextual constraint than did the nonsense syllables. Finally, a triple interaction between grammatical structure, word order, and method of presentation showed that D and PNQ differed most when presented serially in random order. The results could not be explained in terms of a transformation grammar model. On the other hand, frequency of occurrence of single words and combinations of words appear to be consonant with the findings.
References


Martin, J. G., Davidson, Judy R., & Williams, Myrna L. Grammatical agreement and set in learning at two age levels. J. exp. Psychol., in press.


Miller, G. A. The magic number seven, plus or minus two: some limits on our capacity for processing information. Psychol. Rev., 1956, 63, 81-97.


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Table 1

The 10-word Stimulus Series

Declarative Grammatical

Set a - And the piqy kews were behoving the nazer zumaps dygly.
Set b - And the kavy bycs were derizing the tober latuks neply.

Declarative Random

Set a - beboving piqy nazer were the and zumaps kews dygly the
Set b - derizing kavy tober were the and latuks bycs neply the

Passive-negative-query Grammatical

Set a - Weren't the nazer zumaps dygly beboved by the piqy kews?
Set b - Weren't the tober latuks neply derized by the kavy bycs?

Passive-negative-query Random

Set a - beboved nazer the dygly by weren't piqy zumaps kews the
Set b - derized tober the neply by weren't kavy latuks bycs the
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<thead>
<tr>
<th>Variable</th>
<th>Contrasting Conditions</th>
<th>p</th>
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<tbody>
<tr>
<td>Grammatical Structure</td>
<td>D = 1.31</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PNQ = 1.54</td>
<td>NS</td>
</tr>
<tr>
<td>Word Order</td>
<td>Sentence = 1.14</td>
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</tr>
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<td></td>
<td>Random = 1.71</td>
<td>.005</td>
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</tr>
<tr>
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<tr>
<td></td>
<td>Second</td>
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<tr>
<td></td>
<td>Second Presentation = .99</td>
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<td>Method of Stimulus Presentation</td>
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<td></td>
<td>Whole = 1.18</td>
<td>.005</td>
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<tr>
<td></td>
<td>Serial = 1.67</td>
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<tr>
<td>Word Type</td>
<td>Function Word = .77</td>
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<td></td>
<td>Nonsense Syllable = 2.08</td>
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Table 3

Mean Number of Errors per Word for the Conditions
Making up the Grammatical Structure - Method
of Presentation Interaction

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<thead>
<tr>
<th></th>
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<th>PNQ</th>
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<td>Whole</td>
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<td>Serial</td>
<td>1.40</td>
<td>1.93</td>
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p < .05
Table 4

Mean Number of Errors per Word for the Conditions Making up the Grammatical Structure - Stage of Learning Interaction

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<td>Second Presentation</td>
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<td>0.91</td>
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p < .005
Table 5

Mean Number of Errors per Word for the Conditions Making up the Word Order - Stage of Learning Interaction

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<th>Random Arrangement</th>
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<td>1.08</td>
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p < .005
Table 6

Mean Number of Errors per Word for the Conditions Making up the Method of Stimulus Presentation - Stage of Learning Interaction

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<th>Serial</th>
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\[ p < .025 \]
### Table 7

Mean Number of Errors per Word for the Conditions Making up the

Word Type - Method of Stimulus Presentation -

Word Order Interaction

<table>
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<tr>
<th></th>
<th>Function Words</th>
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<th>Nonsense Syllables</th>
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<td>Whole</td>
<td>Serial</td>
<td>Whole</td>
<td>Serial</td>
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<td>Sentence</td>
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<td>.37</td>
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<td>2.43</td>
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</table>

p < .025
Table 8

Mean Number of Errors per Word for the Conditions Making up the
Grammatical Structure - Method of Stimulus

Presentation - Word Order Interaction

<table>
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<tr>
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<th>D Serial</th>
<th>PNQ Whole</th>
<th>PNQ Serial</th>
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<tr>
<td>Random Arrangement</td>
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<td>1.37</td>
<td>2.42</td>
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p < .025