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INDIVIDUAL DIFFERENCES IN WORD FUSION: A METHODOLOGICAL ANALYSIS

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Day recently discovered that when word components such as Lanket and Banket, both derived from Blanket, are presented one to each ear, the components may perceptually fuse into the word, but there are large individual differences in fusion rates. These individual differences may reflect widespread differences in how people process information and therefore may be of considerable theoretical and practical significance. The present research correlated different measures of fusion in an attempt to determine the nature

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) of the basic phenomenon. One measure of fusion is accuracy of temporal order judgements. One component leads the other by 80 milliseconds. If the sounds fuse, then a subject should have difficulty with temporal order judgements. A second task required the subject to ignore the component on the left ear and report the one on the right. Again, fusion should lead to poor performance. The third measure was based on the accuracy of discriminating instances in which a real word occurred on both ears from instances in which the components appeared on the two ears. Fusion should again make such judgements difficult. However, accuracies on the three tasks were poorly correlated and was a maximum of .38 for temporal order judgements and right ear judgements. Furthermore, most people fused very little when assessed by the accuracy of discriminating real words from fused words. The discrepancies with Day's analysis may be due to differences in scoring techniques. The fusion phenomenon appears not to be a true fusion that would impair discrimination of the components. Rather language appears to heavily bias the response of some people.

Tech. Report 2

Individual Differences in Word Fusion:

A Methodological Analysis

by

Steven W. Keele and Don R. Lyon

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Individual Differences in Word Fusion:

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Three measures of Day's word fusion phenomenon were correlated with each other. Day had discovered that when word components such as Lanket and Banket, both derived from Blanket, are presented one to each ear, the components may perceptually fuse into the word, but there are large individual differences in fusion rates. One measure of fusion is accuracy of temporal order judgements. One component leads the other by 80 milliseconds. If the sounds fuse, then a subject should have difficulty with temporal order judgements. A second task required the subject to ignore the component on the left ear and report the one on the right. Again, fusion should lead to poor performance. The third measure was based on the accuracy of discriminating instances in which a real word occurred on both ears from instances in which the components appeared on the two ears. Fusion should again make such judgements difficult. However, accuracies on the three tasks were poorly correlated and was a maximum of .38 for temporal order judgements and right ear judgements. Furthermore, most people fused very little when assessed by the accuracy of discriminating real words from fused words. The discrepancies with Day's analysis may be due to differences in scoring techniques. The fusion phenomenon appears not to be a true fusion that would impair discrimination of the components. Rather language appears to heavily bias the response of some people.

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Individual Differences in Word Fusion:

A Methodological Analysis

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This study is a preliminary investigation of the relationship between different measures of a striking individual difference in perception discovered by Day (1968, 1970). Day presented people with tape recordings of components derived from words. The words were all ones in which a stop consonant (p, t, k, b, d or g) was followed by a liquid consonant (r or l), and examples are blanket, closet, and greedy. Components were derived from the words by eliminating either the stop consonant or the liquid, yielding components such as banket-lanket, coset-loset, and geedy-reedy. When a pair of components such as lanket-banket were presented, one component to each ear at about the same time, many people reported hearing a word: The components apparently fused together despite the fact that an actual word was not present on the recording. Day (1970) reported a particularly striking individual difference. While some people fused more than half the component pairs, other people rarely fused them, and the result was a strong bimodal distribution of number of people plotted against fusion rates.

The individual difference in fusability has generated considerable interest, partly because it appears to be such a powerful, dichotomous difference and partly because it may tap very basic differences between people in cognitive functioning. Day (1973 a,b) for example, found fusers to have shorter digit spans and to be less adept than non-fusers at a language game in which the r letters of words were to be pronounced as l sounds and the l letters to be pronounced as r sounds. Fusers, in Day's terms, appear more bound to normal language. The fusion paradigm is also very similar to the dichotic shadowing paradigm on which classic theories of attention (e.g., Broadbent, 1958 and Treisman, 1964) have heavily relied. Fusion can be viewed as a failure of selective attention to one of two inputs to the two ears. Thus, the fusion task may tap differences in the level of information processing at which individuals select information for further processing. Non-fusers may select information more toward the sensory end and filter or attenuate competing inputs; fusers may selectively attend at the memorial level with different inputs being processed in parallel to that level.

As a prelude to investigations of how the fusion phenomenon relates to other individual differences, a methodological analysis of fusion itself is useful. One methodological question concerns what physical variables influence fusability. Day (1970) investigated the temporal relationships between the components. Whether the onset of the stop consonant led the liquid by up to 100 milliseconds or whether the liquid led the stop by up to 100 milliseconds, temporal asynchronomy had little influence on the proportion of times the components fused. This result was not completely replicated by Cutting (1975), however. He found maximum fusion to occur when the stop led the liquid by 50 or 100 milliseconds. When the stop led by larger amounts or when the liquid led the stop, the percent of fusion responses declined, but fusion still occurred on many occassions. One difference between the two studies is that while Day used natural language components, Cutting used components constructed on a speech synthesizer. Synthetic speech was shown by Cutting to fuse much more readily than natural speech, but its higher fusion rate may also be more sensitive to timing.[1] Other physical variables have remarkably little effect on fusion. Intensity differences of as much as 15 db between the components, fundamental frequency differences of 20 Hz, simulated differences in vocal tract size, and differences on all three dimensions had virtually no effect on fusion rates (Cutting, 1975).

The relative lack of influence of physical variables on fusion suggests that fusion is a fairly central phenomenon, and it has the practical implication that minor differences in the components when constructing natural language tapes are probably of little consequence.

A second methodological question, and the one that this study focuses on, concerns how to measure the fusion phenomenon and how well different measures relate to each other. The procedure primarily used by Day and by Cutting required people to write down what they heard, whether one or two words and nonsense or real words. This procedure, when applied to individual differences, is highly susceptible to response bias--i.e., it may be highly influenced by the subject's expectations about whether words are really recorded or not. In fact, since there are no words, there is no way of knowing whether subjects would be able to discriminate fused words from real words if given an opportunity. This problem is similar to problems with classical approaches to perceptual decisions and criticized by signal detection theory for failing to discriminate between detectability and bias. While the distinction probably is not critical when variables of the sort used by Cutting are investigated, it may be quite critical in assessing individual differences. Techniques for measuring discriminability free from bias are needed to study the fusion phenomenon. Of course bias to fuse may be as important an individual difference or even more important, than discriminability. An understanding of the fusion phenomenon would be fostered, however, by separating the two measures.

One technique explored by Day (1970) involves temporal order judgements. In the experiment in which she explored the effects of temporal asynchronies of the stop and liquid consontants, she also asked people to judge which letter was first (for example in the lanket-banket pair, subjects indicated whether they heard an "l" or a "b" first). Again, there was a large range of individual differences. Day measured the percent correct judgements when the liquid consonant led the stop. Some people exhibited a high percent correct on that measure and some a very low percent correct. Percent correct on the liquid led pairs was negatively correlated with fusion scores, but the correlation was not unity and in fact, was neither reported nor apparently statistically validated. Moreover, the temporal order judgement scores, though exhibiting a broad range were not as noticeably bimodal as fusion scores. Measuring only percent correct on the liquid led pairs again confounds discriminability and bias. A person with an extreme bias to report the stop to lead, might almost always be correct when the stop actually leads and slighly less than 50 percent correct on liquid leading pairs. Such a pattern of results would actually indicate considerable discriminability if the effect of bias were removed. One measure of discriminability that is fairly free of bias is the signal detection measure of d'. Another is the percent correct averaged over both stop and lead and liquid lead pairs. Both of these measures are used in the present study.

In addition to temporal order judgements, it would be desirable to have other objective measures of fusability to determine how they relate to each other. In the present study, three judgement tasks designed to tap fusability were explored. One task involved temporal order judgement. A second task asked subjects to selectively listen to input to the right ear and judge which component (such as lanket or banket) occurred in that ear. Subjects that fuse the pair of components should be unable to judge which component is from the right ear and ignore the component from the left ear. The third task involved word-nonword judgements. On half the trials an actual word was played in both ears. On the other half of the trials, only the component pairs were presented. Subjects were asked to judge whether a real word was present. Again, people that fused were expected to have difficulty on this judgement.

Method

Subjects. Thirty-six native speakers of English participated in the main experiment for two sessions. They were paid $4.00 plus a bonus for accurate performance. All subjects claimed to be right handed and wrote with their right hands. In most cases, subjects were run four at a time, each with a separate set of earphones and with partitions to prevent subjects from viewing each other.

Materials. The stimuli were tape recordings of 22 different words and components derived from the words, and the words are shown in Table 1. Each word started with one of the stop consonants p, t, k, b, d, or g and

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Insert Table 1 about here

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the second letter of a word was the liquid r or l. The components of a word were constructed by the speaker eliminating either the first or second letter as he pronounced the word. For example, the word trumpet yielded two components, tumpet and rumpet. A professional speaker, a former radio announcer, prepared a master tape of the words and the components. When the master tape was slowly moved by hand back and forth over the playback head of the recorder it was often possible to localize the onset of the word or component within a few milliseconds. However, on many of the recordings the onset of speech sound was so gradual that it was difficult to specify where the onset began. In addition, there were occasional noise disturbances near the beginning of the speech sounds. These two problems were corrected by selectively erasing the noise disturbances and the earliest portion of the speech sound to give a sharper onset. Individual pronunciations following the editing were clearly discriminable.

A copy of the master tape was made and the onsets of the speech sounds on both tapes were again determined by passing the tape over the playback head by hand and the onsets were visually marked. The two tapes were then mounted on a pair of Ampex playback units owned by the University of Oregon Audio-Visual Department and rewired for simultaneous starting. The marks on the two master tapes could be aligned with reference marks on the playback units, both units simultaneously started, and the messages transferred to two channels of a third recorder. This procedure allowed the components on the two channels to be aligned within about plus or minus 10 milliseconds of the desired spacing.

Three different experimental tapes were constructed. On one tape, intended for temporal order judgements, pairs of components from the same word (e.g., panet-lanet) were recorded, one component on each channel. One component led the other by 80 milliseconds[2]. Each of the 22 component pairs were recorded twice for a list length of 44. On half of the pairs the stop consonant led the liquid, and on the other half the liquid led the stop. The stop led and liquid led pairs were randomly mixed in order on the tape, and 7-8 seconds intervened between each pair.

The second tape was again constructed from the component pairs, but in this case the onset times were approximately synchronized. This tape was used for right ear judgements. An equal number of stop consonant and liquid consonant components occurred in the right ear and these two types were randomly intermixed in the list. Again the list was composed of 44 pairs with about 7-8 seconds between pairs.

The third tape was designed for word judgements. Half of the 44 pairs in the list were component pairs as before, but with the stop component always leading the liquid component by approximately 80 milliseconds. For the remaining 22 pairs, the same word (e.g., triumph and triumph) was presented to both ears. Because preliminary studies indicated that components that fuse often leave residual cues that components were indeed present, an attempt was made to introduce similar cues when pairs of words were presented in order to make them less discriminable from component pairs. When word pairs were recorded, the word in one ear led that in the other ear by approximately 80 milliseconds and the two recordings of the word were independent pronunciations.

Check lists for the subjects were constructed for each tape. The list for the temporal order judgement and the right ear judgement tapes both listed the 44 component pairs. The list for the word judgement listed the word and the component pair for each of the 44 list positions. Thus, in all conditions subjects were aware in advance of a pair of items what the possible items were.

Procedure. The subjects listened to each of the three tape recordings of 44 pairs in the order temporal order judgement, right ear judgement, and word judgement on each of two successive days. The session on each day lasted about 1/2 hour. Thus, over the two sessions each subject made 88 judgements in each of the three conditions. For the temporal order judgement, it was explained that no words were actually recorded, even though it might on occasion sound as though a word was present. They were to listen to a component pair and then check on the list before them which component they thought began first. Subjects were asked to fix their eyes straight ahead. On the right ear judgement task, they were again informed of the nature of the items and told to listen only to their right ear, checking the component on the list that occurred on that ear. They were asked to turn their eyes to the right. Gopher (1973) noted that most people move their eyes to the side of selection in dichotic listening, even in the absence of instruction, but the instruction was adopted to minimize strategies that could conceivably influence the individual differences in fusability. On the word judgement task subjects were informed that on half the trials there actually would be the same word on both ears and on the other half there would only be components.

Pilot testing had indicated that at least on temporal order and right ear judgements some people perform at near chance levels. As an incentive for people to concentrate on the task despite difficult discriminations, they were paid 3/4¢ for each correct response, yielding a bonus in addition to their normal pay of up to $1.96.

Results

The distribution of subjects by total percent error is shown for each judgement task in Figure 1. On both temporal order judgements and word judgements, people exhibit wide individual differences ranging from about 10 percent error to chance levels of 50 percent error. On the word judgement task the range of scores is much more restricted and people are more accurate. Some people made no errors at all and half made 5 percent or fewer errors. The latter task indicates that pure fusion for most subjects was rather rare. If fusion did occur, there must have been enough residual cues present to allow most subjects to discriminate the fused product from a real word.

Insert Fig. 1 about here

Subjects appear continuously distributed in performance on each of the tasks, and there is little evidence of bimodality in any of the distributions as one might expect from Day's (1970) data. A continuous distribution could occur if abilities on the tasks were truly discontinuous but the assessment was unreliable. Since each task was presented on two sessions, performance on each task was correlated across the two days. The correlations were .65 for temporal order judgement, .81 for ear judgement, and .65 for word judgement. Applying the Spearman-Brown formula for reliability of the score totaled over both days, the test reliabilities are .79 for temporal order judgement, .89 for ear judgement, and .79 for word judgement. Since the tests are fairly reliable, it appears that the distribution of errors on the tasks are not bimodal.

The correlations between tasks are quite small. The Pearson correlation between errors on temporal order judgement and errors on ear judgement is .38; between temporal order and word judgement, .23; and between ear judgement and word judgement, .24. Only the first correlation is significant, and it is significant at the .025 level of confidence.

If subjects tend to perceptually fuse the components to a word, then there might be a bias on the temporal order judgement to say that the stop consonant leads the liquid. Thus errors on that task may be a combination of difficulty in discriminating and response bias. To obtain a more pure measure of discriminability, the temporal order errors were broken down into cases where stop lead stimuli were incorrectly identified as liquid leads and vice versa, and the statistic d' was calculated for each subject as a measure of perceptual discriminability between the two classes. This more refined measure had little influence on the results: d' correlated -.97 with total temporal order errors, indicating little difference in the two measures (Note: that a large d' implies few errors, yielding a negative correlation); d' correlated -.31 with ear judgement and -.27 with word judgement, with only the former being significant at the .05 level of confidence.

The highest correlation, therefore, is between errors on temporal order judgement and errors on the ear judgement and is .38. The correlation presumably would be higher were the two tests perfectly reliable. A correction for attenuation of the correlation due to unreliability estimates the true correlation to be .46.

Discussion

The present study failed to uncover a robust, individual difference in fusion of word components presented separately to the two ears. When an objective measure of fusion was used--i.e., the ability to discriminate real words from "fused" words--fusion did occur but was relatively rare. Averaged over all subjects, only 6 percent errors were made on the task and the range of individual differences was rather small. If some people often fuse words, they should also have difficulty with other judgements about the components. They should be unable to accurately judge, when fusion does occur, which component occurred first. Moreover, they should be unable to tell which component occurred on which ear. Thus, one would expect accuracy of temporal order judgements and of ear judgements to correlate highly with accuracy of word judgements and with each other. There was, in fact, a significant correlation between temporal order and ear judgements, but it was not large.

What reasons might be forwarded for the low correlations? First, poor test reliability would reduce between task correlations. However, test reliability was reasonably high, ranging from .79 to .89. Correction of the highest correlation between tasks, that of temporal order and ear judgements, for attenuation due to unreliability still left only a modest correlation accounting for only 21 percent of the variance in scores.

A second possible reason for the low correlations is that temporal order judgements and ear judgements may be heavily influenced by other individual differences. Thus, some people may be relatively insensitive to temporal order and others may have difficulty in selecting one ear over the other even for items that don't fuse. Day (1970) claimed, however, that people that have difficulty with phoneme temporal order judgements are highly accurate when they judge what ear is stimulated first without regard to phoneme. Unfortunately, the exact correlations of the two tasks are not available.

Third, temporal order judgements and ear judgements might not correlate well with word judgements because of problems with the word judgement task itself. The restricted range on the word judgement task would tend to reduce correlations with other tasks. The actual word judgement task may also be inappropriate--i.e., some people may commonly fuse the components and perceive the components in addition. The perception of the components as well would be sufficient to discriminate between real words and fused words. In fact, on a preliminary test given to different subjects with a different tape, we did not inform subjects of the nature of the stimulus list. We asked them to check whether they heard a word, a component, or both. Subjects often checked both.

To evaluate these last two hypotheses, two new judgement tasks were created. One task, temporal order judgement ear (TOJE) used the same tape as the former temporal order task. However, subjects were asked on the new task to judge which ear received a component first, not which phoneme occurred first. If the correlation between temporal order judgement phoneme (the former task - TOJP) and TOJE is high, then performance on TOJP probably reflects the ability to make temporal order judgements and not only fusion. The second new task called word judgement 2 (WJ2) was a modification of the earlier word task. Half the 44 item pairs were components only as before. The other half of the pairs consisted of an actual word (e.g., BLANKET) presented to one ear and a component (e.g., either LANKET or BANKET) presented to the other ear. Subjects were asked to judge whether no word was present or a word as well as a component was present. As before subjects had check lists with the possible items before them.

Thirty-one of the previous 36 subjects were obtained for two more sessions and run as described for the main experiment on the two new tasks.

The TOJE task was slightly easier than the former TOJP task, but the distribution of subject scores was rather similar. The correlation of the percent correct on the two tasks was .62, uncorrected for attenuation. This result indicates that poor performance on TOJP is determined not only by fusion but also by poor discriminability on temporal order per se. The result, on the surface is also contrary to Day's reported results. A simple model was used to re-evaluate the relationship between TOJP, the old word judgement task, and the right ear judgement task. Essentially the model assumed that an error on TOJP could arise either because of fusion or because in the absence of fusion temporal discriminability failed. The latter component is estimated from TOJE. The model allowed an estimate of the errors due to fusion. Unfortunately, this derived measure failed to correlate as well with other tasks as the uncorrected TOJP.

Subjects made more errors on WJ2 than on the previous WJ task and the scores were distributed over a broader range. However, the new task corretaled more poorly with the old tasks than did the former WJ task.

These results in their entirety suggest, therefore, that the fusion phenomenon studied by Day is not one of pure fusion. If it were, discrimination of words from components, temporal order of phonemes, and ear of entry should be highly correlated. The fact that they are not suggests not only that pure fusion is rare but that the tasks involve fairly independent abilities.

How are these results to be reconciled with Day's work? Day found that TOJP was related to the number of fusion responses when subjects wrote down whatever they heard, words or components, or both. On the other hand

TOJP was not related to TOJE. We find just the opposite on both aspects. Finally in Day's work TOJP task is related to a number of interesting other tasks.

Recently, Day (personal communication) described in more detail her more recent scoring techniques on TOJP, which is now her main technique for assessing individual differences. In the earlier report (1970) she differentiated subjects on the basis of percent correct on liquid led pairs of items. As already suggested, this measure is highly influenced by bias as well as discriminability. The more recent procedure is rather complex, but in part subjects are classified as language optional if performance on both stop led and liquid led pairs does not differ substantially and both are 55 percent correct at 50 and 75 msec. onset asynchronies. Subjects are classified as language bound if stop led pairs are correct over 68 percent of the time and liquid led are correct less than 50 percent of the time. Subjects that fail to meet these criteria are not classified. For example, a person that performed at the 50% level on both stop led and liquid led pairs would be non-classified. In our system, such a person would be given the lowest score of no discrimination.

Again, Day's newer classification scheme is highly influenced by subjects' biases in favor of saying the stop leads. Although discriminability is correlated with the classification, some subjects that are classified as one type or the other actually may differ little in discriminability. To provide a concrete example, a subject obtaining 60% correct on stop led pairs and 60% correct on liquid led pairs would be classified cr language optional. The overall percent correct would be 60% and d' would be .81. A subject obtaining 90% correct on stop led and 45% correct on liquid led pairs would be classified as language bound, but the overall percent correct would be 67.5% correct and d' would be 1.15. Both overall percent correct and d' is larger for the hypothetical language bound subject, implying better, not worse, discriminability.

Thus, while our measures were relatively pure measures of discriminability, Day's scoring system specifically includes bias. One reason, therefore, that she found no relationship between TOJP and TOJE is that bias in favor of reporting one phoneme first would be unrelated to the biases and discriminability that would operate in TOJE.

More important, the different scoring techniques suggest an important aspect of the fusion phenomenon. The phenomenon appears not to be one so much of actual fusion. If it were, then we should have found higher correlations between our various measures. Rather, the phenomenon seems to be one in which language heavily influences sensory discriminations. The influence is one not so much of impairing discriminability as it is in biasing the answer.

Fusability is probably, therefore, an inappropriate descriptive term for the individual differences. Day's terms of language bound and language optional imply differences in ability to divorce oneself from language influence, and may be more appropriate. This interpretation has implications for the kinds of other tasks that might relate to the present ones.

There are other differences between the Day studies and the present one. The stimulus tapes use different words, they are prepared differently and the exact onset asynchronies of the members of a pair differ. Our subjects were told the nature of the stimuli and made forced choice judgements on checklists; Day's subjects did not know either the exact nature of the stimuli or what stimulus would occur next. These differences might be critical to the different results. Thus, without regard to scoring system, our procedures might reduce the natural bias some people would have in favoring stop led pairs. Despite these differences, we suggest that the fusion phenomenon is not so much an inability to discriminate components of words as it is for language to influence the response.

Footnotes

[1]Cutting, although finding a large range of individual differences in fusability, found only a trace of a bimodal distribution of subjects on fusability. The difference between his results and those of Day's could be due to synthetic vs. natural speech or an inadequate number of subjects in Day's experiments.

[2]The 80 millisecond value was chosen to be large enough so non fusers should have a relatively easy time in temporal order judgements but small enough so the fusion phenomenon should not break down for fusers. Furthermore, it is large enough that minor deviations from the intended time should have little influence on the results.

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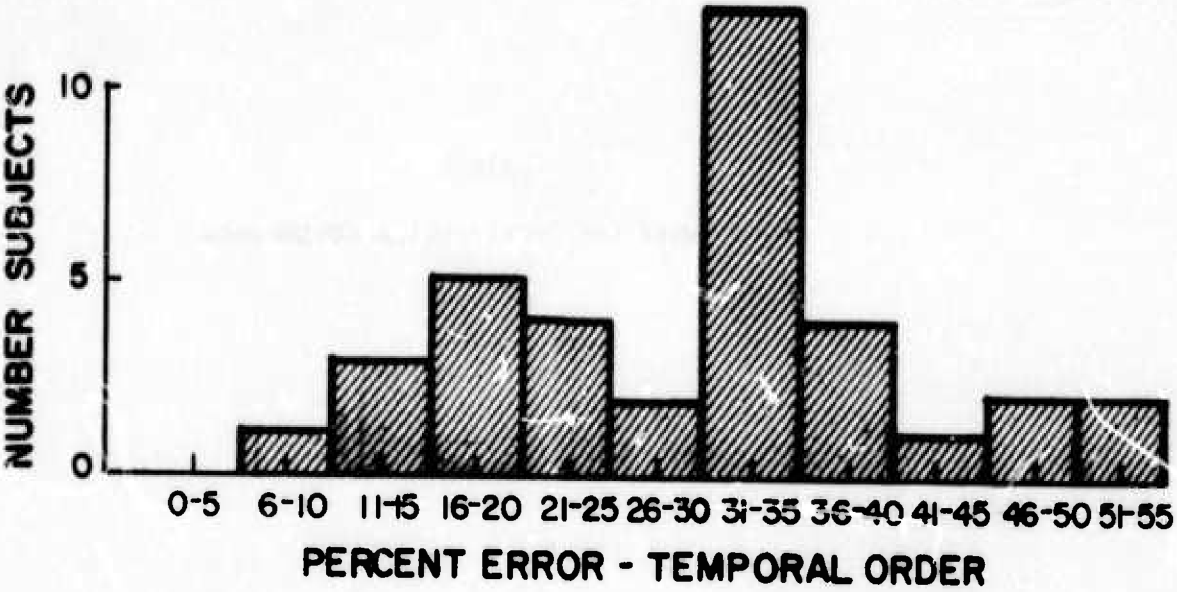
Table 1

Words used for Constructing Components

BLANKET
BLOSSOM
BRACELET
BREAKFAST
CLIMATE
CLOSET
CRACKER
CRYSTAL
DRAGONS
DREADFUL
DROWSY
GLADLY
GLEAMING
GRAVITY
GREEDY
PLACID
PLANET
PRIVATE
PRODUCT
TREATMENT
TRIUMPH
TRUMPET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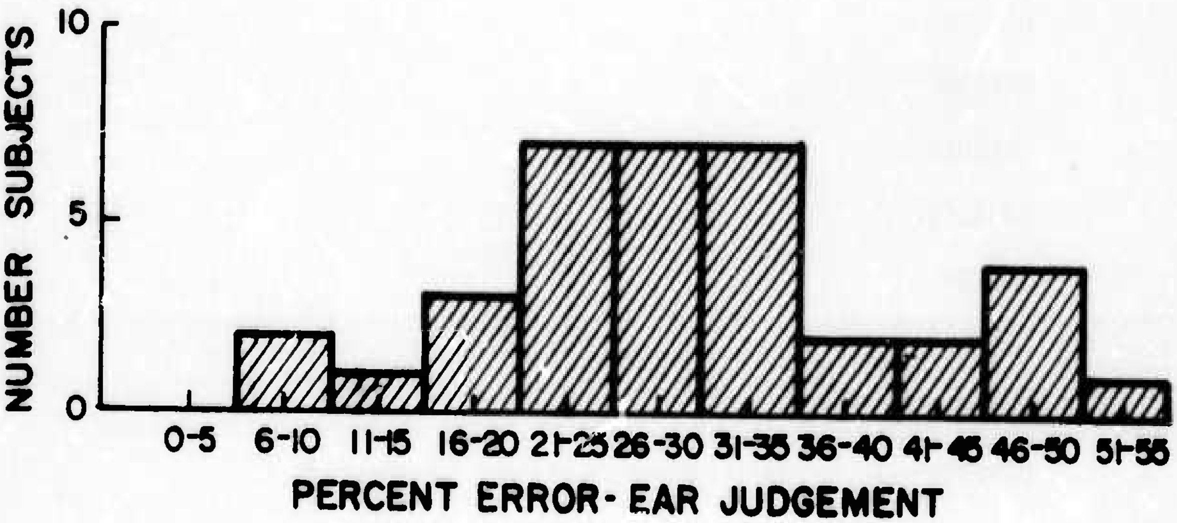
5
0
0-5
6-10
11-15
16-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
PERCENT ERROR - TEMPORAL ORDER


NUMBER SUBJECTS
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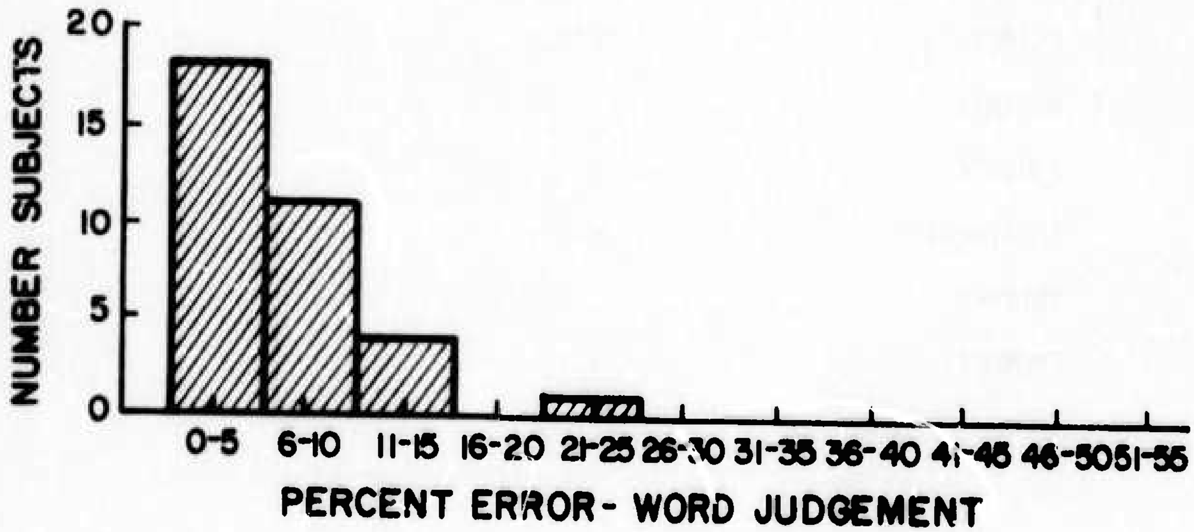
0-5
6-10
11-15
16-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
PERCENT ERROR- EAR JUDGEMENT


NUMBER SUBJECTS
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0
0-5
6-10
11-15
16-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
PERCENT ERROR- WORD JUDGEMENT