Word Recognition Latencies as a Function of Form Class, Stem Length, and Affix Length

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This study investigated the effects of form class (nouns or verbs), stem length (3–10 letters per word) and affix length of inflected verbs ('ø,' '-s,' '-ed,' or '-ing') on the recognition latency of visually presented stimuli. Stem length proved to be a significant source of variation for all words and for the noun stimuli separately, but not for the verb stimuli. Subsequent analysis of the verb data revealed that stem length was a significant source of variation only on the first block of trials and that the additional time required for processing affixes is reduced between the first and fourth block of trials. The data fit a letter-by-letter interpretation of the recognition process, modified by a possible morphemic segmentation strategy for affixes.

The early work of Cattel in comparing recognition times for words versus letters has been taken as evidence that words are recognized as wholes in a manner similar to the way that individual letters are recognized. There is a more important aspect of the studies Cattel conducted. For example, Cattel (1885) measured the "threshold times" necessary for subjects to accurately report one half of the letters from a tachistoscopic display. Consistently, there was a difference on the order of ·1 seconds between the threshold times necessary to complete the task when the display consisted of short words (4 or 5 letters) versus long words (over 8 letters).

Huey (1908, p. 101) reported the amount of time subjects needed to read entire lists of fifty items—letters or words of varying lengths. He found a 2·3 second difference between a list of fifty four-letter and fifty eight-letter words. A list of fifty twelve-letter words took an additional 8·9 seconds, and 15·6 seconds more were required over the twelve-letter list for a list of fifty sixteen-letter words.

The implication seems obvious if not particularly strong: length is a determinant for either recognition or reading time for words. But it is not satisfying to leave the conclusion at that point. The grossness of the measures employed by Huey and Cattel as well as the lack of any

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standard for determining how large differences must be to reach significance demand a more precise assessment of the issue.

Gibson and Guinet (1971) conducted a study which investigated some of the boundary conditions for length factors in word recognition. Displaying words for a fixed amount of time on a tachistoscope (·33 seconds for adult subjects, ·67 seconds for children), they found more errors as a function of length—4-, 5-, or 6-letter verbs. The verbs were all regular; i.e., of a class that can be inflected with '-s,' '-ed,' and '-ing.' They concluded that inflections tended to function as perceptual units, compared to non-inflectional word endings, but that inflections did not increase the length of a word that could be read. Analysis of errors made at a fixed exposure time does not seem a sufficiently sensitive measure for studying the effect of length on recognition.

Stewart, James, and Gough (1969) and Gough (1972) developed another technique for investigating the issue. They presented nouns varying in length from three to ten letters and asked subjects to read them as quickly as possible. Latency to initiate the response was taken as the dependent variable. They found, as the length of words increased, an increasing but negatively accelerated function for recognition times. In addition they used a production task (subjects were told to say a particular word when a light flashed) which showed that production was relatively constant over all lengths. This would indicate that the increase observed as a function of length was due to recognition.

The present study was designed to investigate the processing of verbs, both uninflected and inflected, to determine just how much time is required to process an inflection. If processing is limited to a letter-by-letter integration, then adding inflections should increase the recognition time proportionately for inflections of different lengths. If processing is morphemic, then there should be no differences among the verb inflections used by Gibson and Guinet (1971).

Method

Stimuli: The verb list was composed of 48 words, twelve each of 4, 5, 6, or 7 letters. All verbs were regular in conjugation. They were equated for frequency between lengths using the Kučera and Francis list. For each stem 'ø,' '-s,' '-ed,' and '-ing' were added, producing four forms of each verb. A randomized list of all the words plus all the inflected forms was produced with the restriction that a stem could appear once in each of four blocks. This yielded a balanced list of all verb stems and stems plus affixes containing 192 entries.

The list of nouns used by Stewart, et al. (1968) contained 192 words also, 24 of each letter length from three to ten. This list was randomized, and included in the present study as a second word list.

Design: The basic design used was a repeated measures factorial with the following factors: Form class (nouns or verbs), word length (for nouns, 3-10 letters; for verbs, 4–7 letters, excluding inflections), and affix type (for verbs only, 'ø,' '-s,' '-ed,' or '-ing'). Subjects were given both lists (nouns and verbs) in balanced orders.

Subjects: Thirteen undergraduate psychology students at the University of Texas were used in this study. They were given course credit for participating.

Procedure: The stimulus words were presented on oscilloscope displays controlled by a PDP-8i laboratory computer. The presentations of each word were controlled by the subject, who pressed a button when ready. Pacing was limited by the computer program so that a response could not be made more often than once every five seconds. Latencies were taken with a Scientific Prototypes voice activated relay and were recorded on line in the computer. Each subject was given several trials with a list of unrelated words, in an effort to control for warm-up. Sessions lasted about 30-35 minutes.

Results

For the first analysis, a subjects × form class × length analysis of variance for repeated measures was conducted. Only the verb data for the items without inflections and the noun data for 4, 5, 6, and 7 letters were used. The only significant source of variance was that for length: $F\,(3{,}36) = 6{\cdot}92$, $p < {\cdot}05$. The means for the four lengths, from four to seven letters are respectively: 603, 592, 590, and 634 msec.

A subjects × length analysis was conducted on the full set of latencies for nouns, from 3 to 10 letters. Length proved to be a significant source of variance again: $F\,(7{,}84) = 9{\cdot}02$ $p < {\cdot}001$. The eight means from 3 to 10 letters are respectively: 604, 625, 608, 613, 657, 634, 686, and 666 msec. Trend analysis showed the linear and quadratic components were significant ($F\,(1{,}84) = 44{\cdot}19$, $p < {\cdot}001$; $F\,(1{,}84) = 6{\cdot}66$, $p < {\cdot}05$).

An analysis was performed on the verb data alone. This was a subjects × affix type × length analysis of variance. Length was not found to be a significant source of variation although affix type was: $F(3{,}36) = 4{\cdot}10$, $p < {\cdot}05$. The means for the four affixes summed over stem lengths were: 'ø' = 586 msec.; '-s' = 584 msec.; '-ed' = 591 msec.; and '-ing' = 617 msec.

Because the length effect showed up in the noun data but not the verb data, it was suspected that the repeated practice on the verb stems washed out differences between the lengths. Thus, separate subjects × affix type analyses of variance were conducted on each block of data. (In each block, there was only one occurrence of each verb stem.)

For the first block, length proved to be a significant source of variance; $F(3{,}36) = 8{\cdot}70$, $p < {\cdot}001$. The means for the four lengths summed over affixes were 598, 618, 611, and 665 msec for 4, 5, 6, and 7 letters, respectively. The linear trend component was significant: $F(1{,}36) = 19{\cdot}39$, $p < {\cdot}001$. When the means for the four stem lengths (without affixes) were examined, the means were: 562, 587, 616, and 648 msec. The linear trend for these means was also significant: $F(1{,}108) = 6{\cdot}93$, $p < {\cdot}025$. Affixes did not have an effect on recognition latency: $F(3{,}36) = 1{\cdot}43$, $p > {\cdot}05$.

The second block analysis revealed no effect on length, but affixes were a significant source of variation: $F(3{,}36) = 12{\cdot}08$, $p < {\cdot}001$. The means for the four affixes were: 577, 567, 612, and 624 msec. for 'ø,' '-s,' '-ed,' and '-ing,' respectively. The analyses for blocks three and four revealed no significant effects for either length or affixes.

When the stems alone were compared with the stems + affixes, the following results were obtained for the first block: (stem + '-s') — (stem) = 24·5 msec.; (stem + '-ed') — (stem) = 24·0 msec.; and (stem + '-ing') = 30·2 msec. An orthogonal comparison revealed that stems plus affixes required significantly longer recognition latencies than stems alone: $F(1{,}108) = 4{\cdot}55$, $p < {\cdot}05$. The same analyses on the other three blocks revealed no significant differences between stems and stems plus affixes. It is of interest that for block four the differences are 14, 9·7, and 13·8 msec. additional time for adding '-s,' '-ed,' and '-ing.'

Discussion

The results of these experiments reveal several important findings. First, the previous findings with regard to length were generally replicated. That is, the general increase in recognition time as a function of length seems to be an established fact. The data for the nouns is of approximately the same shape as the Stewart, et al. (1968) data. Verbs seem to show similar effects to those found by Gibson and Guinet (1971) in their error analysis.

A second important finding is illustrated in the block two data. The addition of an inflectional ending adds a constant amount of time to the recognition latencies—about 25–30 msec. Even more striking in the data is the fact that this additional time is approximately the equivalent to the increase in recognition latency when a single letter is added to a verb stem. This also compares with the Stewart, et al., finding of a roughly constant increment in latencies as a function of length.

The third significant result is that with practice (from block one to block four) the effects of length and affixes vanish. The data seem open to two possible interpretations. First, subjects may develop a strategy of using the first letters of the inflectional endings to identify the whole ending. The alternative would be that subjects use a dual processing mechanism whereby they scan the words for length first and then segment the word morphologically. These two alternatives are not tested unambiguously in the present data, but some evidence is available to support the latter choice. Practice washes out the differences among stem lengths almost completely, but only decreases the time for inflectional recognition from about 26 to 13 msec. This would indicate that the scanning time is decreased for the stems, but the segmentation time for the words remains constant. Scanning time is conceived of as a letter-by-letter search of the word. Segmentation time involves dividing the word into morphological components. If this is the case, the 13 msec. figure (in block four) for the addition of an inflection might be a close estimate of the amount of time necessary to do the segmentation.

In general the least theoretical effort seems to be expended in a letter-by-letter interpretation modified in the following way. It would appear that the subject begins by using a strict letter-by-letter approach, but begins to realize that there are other strategies for recognizing the words. The subjects test various hypotheses which lead to progressively better performance before they become fully adept. In the present data, the naive state (letter-by-letter) is reflected in the block one data. The hypothesis testing stage occurs roughly in blocks two and three. Subjects seemed to become fully sophisticated by block four.

Morphemic analysis in word recognition has not been established as a general effect beyond the case of verb inflections. However, the present findings stress the need for such investigations.

One final consideration seems appropriate for the present study as well as for most "reading" studies which use word recognition tasks. Clearly such tasks do not assess the full range of cognitive processes involved in reading in context. Studies of the processes involved in contextual reading need to be based on solid theory and methodology. These more restricted word recognition studies can provide the foundation for both.

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