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THE UNIVERSITY OF ALBERTA

SUPRA-LETTER SUBUNITS OF WORD RECOGNITION

BY

JOHN TIMOTHY GILLESE

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **Supra-letter Subunits of Word Recognition** submitted by **John Timothy Gillese** in partial fulfilment of the requirements for the degree of Master of Science in Psychology.

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ABSTRACT

In general, studies examining supra-letter subunits active in lexical access have focused on word fragment effects. We felt that the presence of specifically identifiable words embeded within whole words would alter lexical access for the whole word. Compound words were selected for study because a single division of these words were selected for study because a single division of these words results in two separate (subunit) words - e.g., COWBOY. In the first experiment, subjects were asked whether presented words could be split into two separate real words. The results indicated a reverse frequency effects for compound words, while the length and frequency. Experiment 2 used a lexical decision task to show that subunit word frequencies had effects on whole word processing. Experiment 3, a repetition priming task, showed that subunit repetition can, in some cases, be detrimental to the subsequent recognition of a compound word or nonword. The results are consistent with interactional models where semantic variables combine with stimulus information in lexical access.

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INTRODUCTION

This research is concerned with the processes that allow for the recognition of words. Most accounts concerning this skill have been directed toward attributes of presentation (stimulus intensity, degrading, masking, context) or whole word attributes, per se (frequency, word length, concreteness, number of meanings, etc). Relatively little research has been directed towards the possible influence of subunits of words (letters, bigrams, prefixes, suffixes, syllables, etc). Therefore, two lines of evidence will be marshalled to support the existence of subunit effects: 'top-down' effects that operate on the basic units of perception, and 'bottom-up' effects that are evident in whole word recognition.

Letters are an obvious physical component in words. It is not surprising then, that letters have emerged as identifiable basic units in the process of word recognition (for extensive reviews, see Estes, 1975; Mayzner, 1975; but also see McClelland, 1976; McClelland, 1977; Papp, Newsome, McDonald, & Schvaneveldt, 1982; Rumelhardt & Siple, 1974). Letters also act as psychological subunits in the sense that they are susceptible to "higher-order" influences. For example, letters in briefly displayed words are reported more accurately than letters in nonwords (for reviews, c.f. Krueger, 1975; Reicher, 1969; Smith & Spoehr, 1974; for comprehensive review, see Baron, 1978; for recent review, see Marmurek, 1986).

The exact nature of these "higher-order" influences seems controversial. For example, this word superiority effect can easily be abolished by letter-position precuing (Johnston, 1981), or by omitting the pattern-mask after word presentation (Johnston & McClelland, 1973). In certain cases, the addition or deletion of a single letter can actually produce poorer discrimination of target letters in words compared to nonwords (i.e., produces a 'word-inferiority effect', Chastain, 1986).

The locus for this effect, however, is not necessarily the cognitive representation of the word, as these cognitive influences can be demonstrated in some cases with nonwords (Solman, May, & Schwartz, 1981). Even though word superiority effects using nonwords are heavily influenced by 'wordness' (pronounceability and approximation to English orthography), these variables do not explain all letter encoding effects (Chastain, 1981; Schindler, Weil, & Pollatsek, 1976).

Egeth and Santee (1981) have shown that letter recognition is dependent on associated letters independent of words, and these effects cannot be explained entirely in perceptual terms (i.e., inhibition between visual features). Mason (1982) showed that position effects, as are found in letter recognition extend to digits and symbols, wth the conclusion that "higher-order" processes must be involved in letter perception (pg. 737). Certainly, these digit or symbol strings could not be construed as 'words' in any sense, yet the effects in this study are quite consistent with those of Egeth and Santee.

It would seem there is a higher-order process 'or processes' acting on letter perception. These effects are not necessarily word-related, because a variety of pseudo-word and nonword stimuli can produce similar effects. This does, however, implicate a supra-letter process, possibly acting enroute whole word recognition. This interim process acting between letter perception and word recognition should also be evident as a 'bottom-up' effect in word recognition.

In considering similar influences on lexical access, several types of supra-letter encoding processes or units have been suggested. Perhaps the simplest hypothesis is that supra-letter subunits are simply increasing numbers of letters (digrams, trigrams, etc.). Certainly digram effects in lexical decision (word recognition) have been documented (Rumelhardt & Siple, 1974). However, the effect is often paradoxical: high frequency digrams sometimes slow recognition times to low frequency words (Biederman, 1966; Rice & Robinson, 1975). Also, there are contradictory reports that fail to show bigram frequency effects (Manelis, 1974; Chambers & Forster, 1975) or letter-cluster effects (McClelland & Johnston, 1977).

Other authors postulate that word recognition is based on phonologic subunits, or syllables (Spoehr & Smith, 1973; Smith & Spoehr, 1974; Spoehr & Smith, 1975). In those proposals, the way a word sounds is postulated to consistently influence its recognition in written language. Phonologic encoding of some whole words receives some support (Meyer, Schvanelveldt, & Ruddy, 1974) and the effect extents to nonwords as well (Rosson, 1983). However, phonologic encoding effects fail to generalize across different types of polysyllabic words (Hillinger, 1980), suggesting that syllabic encoding might not be a consistent process enroute whole word recognition.

Alternatively, Taft (1979) has put forth a theory of word recognition based on the existence of a purely written supra-letter subunit. He has proposed a syllable-like subunit (called 'BOSS') that is constructed along more or less morphemic boundaries, always using the constraints of English orthography (for recent review, see Jordan, 1986). Taft and his associates provide evidence for the existence of BOSS units in lexical access (Taft, 1975; Taft & Forster, 1975; Taft & Forster, 1976; Taft, 1979(a); Taft, 1979(b); Taft, 1981). More recent investigations, however, have failed to support BOSS as a unique unit that functions consistently in lexical access (Lima & Pollatsek, 1983; Jordan, 1986).

Thus, there seems to be the implication of supra-letter subunits active in the cognitive, rather than perceptual, aspects of letter processing and lexical access. Although the exact nature of these higher-order influences in letter recognition is still uncertain, some effects are obvious and consistent. The research, however, has failed to unequivocally demonstrate a similar supra-letter unit or process that consistently influences word recognition. One reason for this failure may be the number of postulated subunits, some of which (for example, BOSS) remain controversial despite a decade of research. If the aim is to demonstrate subunit effects, perhaps the approach should involve a subunit that everyone agrees upon.

Whole words are the most commonly identified unit to demonstrate real effects on letter processing (c.f., Reicher, 1969; Wheeler, 1971). Physical attributes like word shape, although implicated (Monk & Hulme, 1983), are not generally considered important (Bowhuis, 1978; Papp & Ogden, 1981; Abramovici, 1983). The effects are probably more related to conceptual or cognitive issues. For example, the detection of misspellings in words can be dictated by word function (Haber & Schindler, 1981) or by word frequency (Healy & Drewnowski, 1983). Whole words also can affect the processing of other whole words: semantically (Lupker, 1984; O'Conner & Forster, 1974) and contextually (Meyer, Schvaneveldt, & Ruddy, 1975; Stanovith & West, 1983), as well as morphemically (Stanners, Neiser, Hernon, & Hall, 1979) and phonologically (Meyer, Schvanelveldt, & Ruddy, 1974; Underwood & Thwaites, 1982). Thus a processing approach that used whole words as subunits might well be more profitable in illustrating a subunit effect in lexical access.

In addition to using a well-defined unit with reliable and generalizeable effects, a demonstration of subunit effects seems most likely with the use of a strong and consistent experimental effect. A very consistent finding in visual word recognition is the beneficial effect of linguistic frequency in lexical decision tasks (Atkinson & Juola, 1973; Treisman & Parker, 1978). Linguistic frequency refers to the normative frequency of written words in printed material, like magazines and newspapers. (For recent reviews of the 'paradoxical' effects of word frequency accross different experimental paradigms, see Glanzer &

Bowles, 1976; Mandler, Goodman, & Wilkes-Gibbs, 1982.) One of the most common and robust findings is that higher frequency words are subject to faster reaction times and reduced errors in lexical decision tasks (Becker, 1976; Forster, 1981).

In fact, frequency has been said to be the most distinctive factor governing recognition times in lexical decision (Whalley, 1978). Frequency effects have not only been found using whole words but also with single letters (Krueger, 1975), and inconsistently even with bigrams (for recent review, see Gernsbacher, 1984).

Combining this agreed-on supra-letter cognitive unit ('word') with the most reliable predictor of word recognition latencies (frequency) should have strong potential for illustrating a subunit effect in lexical access, if one exists. Although many words have other words embeded within, only certain words are constructed completely from real word subunits. These words (e.g. COWBOY), known as compound words, are generally only formed from other words.

Therefore, in an attempt to maximize whatever possible effects might exist for internal units, compound words were selected as stimuli for the following series of experiments. Here the subunits are themselves real words. Thus the frequency of these subunit (i.e., constituent) word units can be varied, and varied at more than one location. Findings concerning compound words might provide a powerful analytic tool for understanding the role of frequency in word recognition, per se. More specific to the question of supra-letter subunits, the results could have important implications for the ways in which subunit word attributes (i.e., frequency) exert their influence on whole word recognition.

The goal of this research was twofold. The first c[illegible]ern was whether parts of words are themselves perceived as units enroute to whole word recognition. The second but related concern was whether the effects of word frequency differed for compound and complex words.

Compound words, because of their unique construction, may be interesting in their own right. The compound/complex comparison, however, should do more than just provide a control group. The morphologically complex words have been among the most studied words: for example, the previously cited work by Taft and his colleagues. Thus, the comparison of compound and complex words may allow this literature to be interpreted in a different way.

Even though much of this research is confusing, it may be applicable to whole word effects. There is certainly evidence to suggest the existence of some type of supra-letter unit active in polysyllabic lexical access (for review, see Lima and Pollatsek, 1983). Some data favor syllabic or phonologic units (op. cite., Lima & Pollatsek, 1983, Exp't 1; Spoehr & Smith, 1975). Other studies indicate a purely morphemic access code (Rubin, Becker, & Freeman, 1979; Stanners, Neiser, & Painton, 1979), while Taft (1981; 1982) continues to support 'BOSS': a combined morphological/orthographic unit that is totally position-dependent (i.e., occurs only with left to right processing). Jordan (1986), however, found a similar structural subunit that is position-insensitive. In the Jordan reseach, facilitation by a previouly presented items was not dependent on the location of the unit within the priming word.

As previously stated, the inconsistencies in this literature may well reflect the lack of correspondence concerning the definition of exactly what constitutes an active subunit during lexical access. Still, there is substantial literature concerning complex words as well as literature concerning simple words. The literature on simple words may be applicable to the subunit items within the compound word; the literature concerning complex words may apply to whole word effects.

Therefore, in detecting subunit influences, it may be more appropriate to directly compare poysyllabic words with compound words within the same task. The combined study of compound and complex stimuli may be more definitive for possible subunit effects in lexical access, as well as providing data about the compound word as a unique lexical entry, per se.

EXPERIMENT 1

In the literature cited earlier, there is nothing specific that indicates compound words behave uniquely when compared to complex words. Thus, the rationale for this first experiment was not elaborate.

Experiment 1 was designed to provide empirical data to support the hypothesis that compound words are processed differently than are morphologically complex words. Regardless of the task, without a substantial finding at this stage, it would seem fruitless to pursue the study of compound words as a distinctive lexical type, or in support of consistent subunit effects in lexical access.

Intuitively it appeared obvious that the major difference between polysyllabic words (e.g., THUNDERED) and compound words (e.g., COWBOY) was the presence of two identifiable lexical units within the confines of the compound word. Therefore, Experiment 1 simply presented stimuli to subjects asking them if the word could be broken into two separate words or not. That is, subjects were asked if only one division of each stimulus could result in two separate real English words. For example, COWBOY can be split as COW and BOY; the split yields two, and only two separate lexical units. There is no division of THUNDERED that results in two separate, identifiable words.

METHOD

Stimuli and Subjects. Experiment 1 used the same 96 words (48 compound and 48 complex words) as targets. In addition, 12 compound and 12 complex words were used as practice items (All practice items are listed in Appendix A).

The compound words were selected such that only one division or splitting of the whole word would result in two subunits that were themselves real words. As well, the compound stimuli were selected on the basis of global frequency as indexed by Kucera and Francis (1967): low frequency refers to counts of less than 40 per million (median of 4 per million and mode of both 1 and 2 per million) while high frequency refers to counts greater than 50 times per million (range 50 per million to 26,149 per million).

The 48 compound words consisted of four groups of 12 words. These groupings of compound words were made in terms of global frequency (high versus low) and the consistency in the frequency of the subunit, constituent words (consistent versus mixed). Twelve words were high frequency words where both the constituent and global frequencies were high (High Frequency Consistent). An additional twelve words were with whole word high frequency for which one of the subunit words was high frequency and the other low frequency (High Frequency

Mixed). The third group of twelve words were global low frequency words where both subunit words were low frequency (Low Frequency Consistent) The final twelve were low global frequency words where one unit word was high frequency and the other low frequency (Low Frequency Mixed). Thus, frequency was a variable at the level of subunits and at the level of the whole word.

Each compound word was selected such that a single division would always yield two real English words. Although plural forms were allowed, no additional suffixes or prefixes were allowed. Therefore, global or whole word frequency refers to the frequency of the overall word. Subunit or constituent frequency refers to the frequencies of the two individual words that comprise the compound stimulus.

In addition there were 48 complex word targets that were length matched to the compound words and frequency matched to the surface compound word frequency.

The stimuli for Experiment 1 were arranged in two different random sequences with the restrictions that (a) no more than three items in a row required the same response (b) no more than two word items in sequence were from the same frequency grouping. Each subject was randomly assigned to a single block of one of the two orders. Experiment 1 had 96 trials entirely of word stimuli. Thus, stimulus sequence was a between-subjects counterbalancing factor, while stimulus types (compound vs. complex) and frequency (high-low) and internal consistency (consistent vs. mixed) were within-subject factors. The experimental materials are shown in Appendix B.

The participants were all students enrolled in the University of Alberta undergraduate introductory psychology who volunteered as an option for course credit. There were a total of 12 subjects in Experiment 1. Subjects were usually tested in pairs.

Apparatus and procedure. A Micro Tech Unlimited laboratory computer was used to control the stimulus display and record response times. Subjects were seated in adjacent booths about 50 centimeters in front of a (Sony) television monitor. A set of response buttons, located in from of the subject, was used to indicate YES (right index finger) and NO (left index finger) responses. Warning tones were presented through earphones and a fixation dot indicated the center of the area where the stimulus would be presented.

Subjects were instructed to respond as quickly and as accurately as possible. They received 24 practice trials, took a short break, and then completed 96 trials. In this experiment, all stimulus items were real English words. Each trial consisted of a warning tone; 501 ms later the fixation dot ~~was~~ removed and the stimulus was displayed until both subjects had responded (or for a maximum of 2000 ms). The fixation dot reappeared, and about 1500 ms later the warning tone sounded, signaling the next trial.

In Experiment 1, subjects were instructed (see Appendix C) to decide whether the presented stimulus could be split only once, such that the division would result in two real English words. For example, a YES response is correct for the word COWBOY (it can be broken into two real words, COW and BOY). On the other hand, BEAUTIFUL yields a NO response (it cannot be broken into two real words).

RESULTS

For Experiment 1, the mean of all correct reaction times within each stimulus condition was computed for each subject. These data points were treated as independently derived scores. Multiple analyses of variance were performed on both data sets, using both response time (RT) and error rate as dependent measures.

Table 1 lists the results from Experiment 1. Since the YES and NO responses appropriate to the compound and complex items were assigned to different hands, the data from these two types of items were analyzed separately.

A 2 (high versus low frequency) by 2 (consistent versus mixed) analysis of variance was used to analyze

Table 1: Response time in ms (percent in brackets) for the Word-Splitting Task of Experiment 1

	WHOLE WORD FREQUENCY	
	High	Low
Compound		
consistent	762 (1.39)	775 (7.64)
mixed	819 (13.9)	769 (16.7)
Mean	791 (7.64)	772 (12.15)
Complex	1015 (3.69)	1036 (2.85)

the compound words. The error rate analysis shows a reliable difference for frequency, $F(1,11) = 8.19$, $p<.015$, and internal subunit consistency, $F(1,11) = 52.074$, $p<.001$. High frequency compounds had very few errors compared to low frequency, and consistent internal frequency provided for fewer errors compared to mixed frequency. The interaction between frequency and internal construction was not significant, $F(1,11) = 2.099$, $p<.175$.

Analysis of the compound word RT data reveals no significant effect for frequency, $F(1,11) = 2.2$, $p<.16$. Although there is a large difference between high-mixed frequency items and the other forms of compound words, the interaction between frequency and internal subunit consistency is not significant, $F(1,11) = 2.4$, $p<.15$.

Complex words required substantially longer in this task, however, this effect is confounded with handedness and task demands. However, it is important to note that complex words showed a positive frequency effect (faster response times for high frequency items) of about 21 ms whereas compound words showed a reverse frequency effect of about 19 ms. While the main effect is of no interest in a comparison of the RTs for compound and complex words. The interaction is of relevance since the form of the interaction is a crossover effect that could not be attributed to a simple additive effect of decision or response hand. The interaction for the 2 (compound vs complex) X 2 (high vs low global frequency) was reliable, $F(1,11)=2.7$, $p<.09$. This reverse frequency effect for compound words suggests that, at least with this task, they behave quite differently than do complex words.

DISCUSSION

As previously stated (op.cite, Whalley, 1978) the beneficial effects of frequency are well established in visual word studies. The analysis of error rates, however, replicates previous studies showing that high frequency words are responded to more accurately than low frequency words (c.f., O'Connor & Forster, 1981). Subunit word effects were also significant. Regardless of the whole word frequency, consistent internal frequency provided for fewer errors than mixed internal frequency. Within the confines of the current experiment, high frequency complex words are also responded to more quickly than are low frequency words. Compound words, however, show the opposite trend. Low frequency compound words require less time in this word splitting task than do high frequency compounds.

EXPERIMENT 2

Experiment 2 was designed to extend the results of the first study. The RT data of Experiment 1 suggest different effects for the frequency variable on compound and complex words. Examination of the error rates indicates an effect for the frequency of the internal subunits of compound words. However, the interpretation of these data are limited by the uniqueness of the task and the confounding of hand with response type.

Lexical decision task was chosen for Experiment 2 with the belief that the results would be more generalizeable than those of the word-splitting task. The lexical decision task has been used extensively and the results compared with the large body of earlier literature regarding recognition memory (for review, see Bowles & Poon, 1985).

Although the lexical decision task has helped generate much of the existing literature regarding visual word recognition processes (Grossberg & Stone, 1986), the processes underlying the task remain controversial (den Heyer, 1986; den Heyer, Briand, & Dannerbring, 1983; Henik, Friedrich, & Kellogg, 1983; Kiger & Glass, 1983; Smith, 1984).

Despite this controversy, the lexical decision task seems sensitive to many word features that may concern subunit effects: for example, phonology (Parkin, 1982;

Parking & Underwood, 1982), orthography (Bentin & Frost, 1987; Norris, 1984), and morphology (Feldman & Fowler, 1987). As mentioned earlier, frequency effects in lexical decision are also well documented (see also Gardner, Rothkepf, Lapan, & Lafferty, 1987; O'Connor & Forster, 1981). There are differing views concerning the theoretical implications of the lexical decision task and frequency (for recent review, Balota & Chumbley, 1984; Chumbley & Balota, 1984; Lorch, Balota, & Stamm, 1986).

In Morton's (1967, 1970) logogen model, frequency effects (from the lexical decision task) are assumed to occur early in processing. Frequency affects logogen thresholds, that must be exceeded by perceptual and cognitive information in order that lexical recognitiion can occur. However, Becker (1976, 1980) uses lexical decision data to suggest that the effects of frequency determine the order of entry of candidate items into the series of verification cycles. Thus, Becker's theory views frequency as acting relatively late in stimulus recognition. Chumbley and Balota (1984), however, assume that the frequency effects in lexfcal decision reflect a decision (or output) stage rather than affecting lexical access, per se. Because of this emphasis, Balota and Chumbley (1984) indicate that word frequency effects are accentuated by use of a lexical decison task, as opposed to a naming task.

None of these theories address the possibility of any change in the type of processing that might occur when compound words are presented. There is no indication in that the subunit words would be activated nor that the frequency should in any way alter the accumulation of information, activation or verification of the compound. Thus, it seems that current models of word recognition would make undifferentiated predications for the speed and accuracy of frequency matched compound and complex words.

METHOD

Materials and Subjects. Experiment 2 used the same 96 words (48 compound and 48 complex words) for targets as were used in the previous experiment. As well, 96 nonword stimuli were generated by a computer program and length matched to the real word stimuli. These stimuli had digram frequencies at any position of less than 100, with a median value of 54 (Mayzner & Tresselt, 1965). A complete list of all word and nonword stimuli is given in Appendix D.

The experiment was arranged in exactly the same manner as Experiment 1 with the exception that a lexical decision task was used. The subjects were again students enrolled in the University of Alberta undergraduate introductory psychology pool. They volunteered for participation as an option for partial course credit. There were a total of 10 subjects in Experime[illegible].

Apparatus and procedure. The equipment and procedures used were identical to the previous experiment, with two exceptions. In Experiment 2, both word and nonword stimuli were used in the lexical decision task. As well, there was no time limit on responses. All reaction times were recorded as is.

Subjects were instructed to respond as quickly and accurately as possible. The Right key press always indicated a word item, while the Left key press always indicated a nonword item. Subjects received 48 practice trials and 192 test trials.

RESULTS

The data were analyzed in a 2 (stimulus type: compound vs. complex) by 2 (frequency: high vs low) analysis of variance. The mean of all correct reaction times within each stimulus condition was computed for each subject, and multiple analyses of variance were performed using both RT and errors as dependent measures. Only responses to the word items were analyzed.

The reaction time data from the lexical decision task are shown in Table 2 for both compound and complex word items. The effect of frequency was reliable,

Table 2: Reaction Time in ms (percent errors in brackets) for the Lexical Decision Task of Experiment 2.

	FREQUENCY	
	High	Low
COMPOUND		
Consistent	528 (1.67)	610 (6.67)
Mixed	516 (0.00)	590 (5.84)
Mean	521 (0.84)	602 (6.25)
COMPLEX	531 (5.00)	588 (26.67)

F(1,9)=45.7, p<.001. As well, there was a significant interaction between word type (compound vs complex) and frequency, F(1,9)=6.2, p<.05. There was no main effect for word type, F(1,9)<1.00.

The error rates in this experiment are also shown in Table 2. There is a significant difference in error rates for compound and complex words, F(1,9) = 20.8, p<.001, where compound words elicit fewer errors in lexical decision. Not unexpectedly, high frequency words are responded to more accurately than low frequency words, F(1,9) = 39.9, p<.001, and the interaction between frequency and word type is significant, F(1,9) = 28.5, p<.001. Compound words are less affected by frequency than are complex words.

As well, there is a significant effect for internal (subunit) consistency, F(1,9)=7.8, p<.012, and this effect interacts with word type, F(1,9)=9.9, p<.012. In this lexical decision task, internal consistency actually provides for more errors than mixed construction

In Experiment 2, high frequency items were recognized more quickly than low frequency words, thus replicating the usual frequency effect on response times. More importantly for the present goals, frequency effects were modified by the different types of words. Thus, the differential effects of frequency were more marked for compound words and less so for complex items. Compound words showed a frequency effect of 81.25 ms while complex words show an effect of only 56.80 ms.

One difference between the compound and complex items is the presence of subunits in the compound words. Reaction times in Experiment 2 for compound words were analyzed separately for internally mixed and consistent frequencies. The effect is not significant in this analysis, $F(1,9) = .92$, $p<.36$), although the subunit frequency effect is noticeable in the error rate analysis here, as it was in the error rate analysis of Experiment 1.

DISCUSSION

The results of Experiments 1 and 2 have provided evidence that compound words are different than complex words (at least in some circumstances). In Experiment 1, high frequency compound words required more processing time than low frequency compound words. Although not significant, these results were quite different than expected and were opposite to those of the complex words. The complex words in that experiment showed the expected frequency effect: high frequency words were responded to more quickly than low frequency words.

Using the lexical decision task of Experiment 2, word type (compound vs. complex) interacted with whole word frequency (high vs. low). This interaction was demonstrated for both response time and error rates. In both cases, an obvious variable that may account for these differences, is the subunit items in compound words.

Along these lines, the results directly pertaining to subunit frequencies have been disappointing. Although the reaction time data of Experiment 1 appear to indicate differences ascribable to subunit frequencies, these differences are insignificant. In Experiment 2, the effect of internal consistency on response times is not significant, and the pattern of results is not consistent with Experiment 1. Although the error rate analysis shows significant effects for internal consistency (i.e., subunit effects) for both experiments, again the pattern of results is inconsistent between the two data sets. In practical terms, although these two experiments indicate a possible subunit effect, the data are very difficult to interpret.

As well, Experiments 1 and 2 are limited in terms of stimulus materials. For example, high frequency compound words are usually formed from high frequency subunits. Low frequency words are generally formed by low frequency units. In fact, it is almost impossible to find a low frequency compound word that is composed of two high frequency words, or vice versa.

Yet the overall results indicate that compound words show processing differences compared to complex words, possibly indicating a subunit effect. Hence, a third experiment was designed whereby internal subunit frequencies could be manipulated experimentally. Perhaps 'creating' some of these combinations that do not normally exist will provide a means of investigating subunit effects in compound word recognition.

EXPERIMENT 3

In the lexical decision task, there is a benefit to both speed and accuracy for words that are repeated during the experiment (Forbach, Stanners, & Hochhaus, 1974; Kirsner & Smith, 1974). Some authors have proposed that these 'repetition effects' may account for, or at least contribute to, the frequency effects commonly encountered in reading tasks (Dixon & Rothkopf, 1979) and lexical decision experiments (Scarborough, Cortese, & Scarbourough, 1977).

In fact, Jacoby (1983) has proposed the repetition task as an experimental analog of naturally occurring repetition effects. Although repetition affects all items, low frequency words benefit much more from repetition than do high frequency words (for recent review, see Forster & Davis, 1984). These results are not consistent with either the logogen-based models (i.e., Morton, 1969) or the lexical search (c/f., Becker, 1979) theories of word recognition. (For recent reviews concerning this inconsistency, see Forster & Davis, 1984; Jacoby, 1983; Johnston, Dark, & Jacoby, 1985; Logan, 1985; Tulving, Schacter, & Stark, 1982).

Even if both models were able to accomodate these data with significant changes, neither theory would expect repetition effects to be anything but short-lived. Yet, repetition effects have been demonstrated for 24 hours in visual word identification (Jacoby & Dallas, 1981), at least seven weeks with non-word consonant strings (Schindler, Well, & Pollatsek, 1976), and lasting up to a year with the reading of inverted text (Kolers, 1976).

Thus, the theoretical implications of repetition priming (perceptual fluency) are controversial. However, the effects are consistent: across time (as previously stated), and across experimental paradigms. For example, Jacoby and Dallas (1981) showed that prior exposure to a word increased the probability of detecting that word in a brief tachistoscopic display. Tulving, Schacter, and Stark (1982) used prior presentation of a word to improve performance on a word-fragment problem, and other experiments have shown repetition effects using a lexical decision task (e.g., Scarborough et al, 1977).

Repetition effects can also be demonstrated with nonwords (Feustal, Shiffrin, & Salasoo, 1983; Schindler et al, 1976). However, the effects tend to be smaller (Scarborough et al, 1977), insignificant (Forbach et al, 1974), or specifically related to the experimental paradigm (Feustal et al, 1983).

Supra-letter subunit priming effects are usually examined through the repetition of morphologically similar words (for recent review, see Fowler, Napps, &

Feldman, 1985; Steinberger & MacWhinney, 1986). For morphologically similar words, repetition priming effects can sometimes be substantial (Fowler et al, 1985; Jordan, 1986). Other studies, however, have shown a variable and often quite diminished pattern of results (Lima & Pollatsek, 1983; Murrel & Morton, 1974; Stanner et al, 1979). Again, the difficulty in obtaining consistent effects seems related to debate about what constitutes an effective subunit in lexical access. Most notable, these studies have all used polysyllabic or affixed words. However, with compound words, an obvious unit of access might involve the real constituent words as opposed to word fragments or chunks used from the complex or polysyllabic words.

In Experiment 3, repetition priming was used in an attempt to more fully investigate the relationship between the subunit words in the lexical access for compound words. Again, polysyllabic words were used as appropriate controls. For both types of words, the effects of repetition were compared for whole word repetition versus unit repetition. For example, COWBOY was preceded either by itself, COW, or BOY, or an irrelevant item. PRACTICE was preseded by itself, PRAC, TICE, or an irrelevant item. As well, comparable conditions were used with the pseudo-compound words: for example, SEAFACE was preceded by itself, SEA, FACE, or the irrelevant condition. The same conditions were applied to the pseudo-complex non-words. For example, THOUSFECT was preceded by itself, THOUS, FECT, or an irrelevant item.

It was anticipated that high frequency words would be recognized more quickly than low frequency words. In keeping with Jacoby's 1983 results, the previous presentation of a whole word should preferentially (although not exclusively) affect low frequency words compared to high frequency words. As well, it was anticipated that the effect of internal repetition would be different for surface high and low frequency items. High surface frequency items should be least sensitive to unit repetition: repeating a subunit in the high frequency items should be almost undetectable.

Low surface frequency items are predicted to be more sensitive to subunit repetition. If the subunit items within compound words are processed as individual words, repeating a subunit in the low frequency items should provide strong results that may well differ depending upon the position and frequency of the repeated subunit.

Subunit frequencies were disappointingly poor predictors of reaction time performance in the first two experiments. Therefore, Experiment 3 concentrated on reliable stimuli, regardless of the internal subunit consistency (i.e., frequency). In fact, internal consistency was confounded in the design because of the low number of adequate and reliable compound stimuli.

Regardless of subunit consistency, however, the effect of subunit repetition was predicted different for surface high versus low frequency compound words. The earlier experiments indicated that subunit frequencies may be active enroute whole word recognition. These effects differ (i.e., interact) with the different task demands of the first two experiments. Thus, in Experiment 3, surface frequency is predicted to interact with the repetition (i.e., manipulated frequency) of the internal subunits.

However the subunit words of compound words may not be processed as units, or at least no differently than the 'subunits' of complex words. If so, the effect of repeating a word-part should be entirely due to the responses appropriate to the fragment presentation. That is, the subunits of the compound items are words, and the correct response is "word". However, the fragments from the complex words are letter strings that do not form a word, hence the appropriate response is "nonword". To the extent that these responses become associated with the subunits, one could anticipate a general response slowing with fragment repetition in complex words, and a general facilitation with compound words.

METHOD

Materials and subjects. Because the subunit of lexical entry for polysyllabic (complex) words is debatable (as previously discussed), the stimulus materials, per se, were of singular importance. Although the unit of access is still debatable for compound words, there are two obvious choices (WORD-1 and WORD-2) and both these choices were utilized in this experiment. For complex words, however, the division point for subunits (I elected to use only two units) was decided empirically.

Both high and low frequency complex words were given to 16 volunteers with instructions to "divide the word only once where it seems most natural". Words were selected on the basis of dictionary defined syllabic boundaries concuring with the author's own intuition as to a "natural" break. The data obtained from the volunteers was scored for concordance with this same, arbitrary, boundary.

As well, the same volunteers were given all the nonword stimuli and all the nonword stimuli (see Appendix E) with the same instructions. A criterion of 2/3 consensus (thus 11/16 people or 68.75%) was used for acceptance of items for inclusion in the stimulus list.

The percent consensus for the stimulus materials is shown in Appendix F. Interestingly, there was 100% consensus for all compound words, and almost 100% consensus for nonword (constructed) stimuli. The complex words were chosen to be above 68.75% concordance. However, for the 39 tested low frequency complex items, the range of consensus was 12.5%-93.75% and the mean 68.1%. For the 42 tested high frequency complex words, the range was 12.5%-93.75% and the mean 56.7%. Only items exceeding the criterion were used in the experiment.

Because Experiment 3 was specifically designed to examine the effects of sub-units on whole word recognition, all stimuli were selected on the basis of these specified identifiable subunits. Using frequency as the major independent variable, the complex words were frequency matched to both the high and low frequency compound words. Each group of 12 items was length matched (to within 2%) to every other group of 12 items.

Non-word stimuli were constructed from words or word subunits in the following way. Each unit word in a pseudo-compound nonword was frequency matched to the appropriate unit in a control compound word. As well, these pseudo-compound foils were constructed such that there was no discernable associative strength between the subunit items, according to the 1952 Minnesota word

Association Norms (Jenkins, 1970). For example, THINPOOL is constructed of THIN (frequency matched to BASE) and POOL (frequency mated to BALL). BASEBALL is the real compound word; THINPOOL is the matched control nonword.

Pseudo-complex stimuli were constructed from the first or last portions appropriately of frequency matched complex words. For example, BEAU (a first potrion, frequency matched to PRACTICE) and MANCE (a second word portion, again frequency matched to PRACTICE). Thus, both portions were selected from real English words, matched to the frequency of the complex word. Then, the portions were selected and combined on the basis of their pronounciability and correspondence to English orthography.

Using these stimulus materials, each subject saw every item in a lexical decision task. And, every item was preceded either by itself, by the first unit, by second portion, or by an unrelated, irrelevant item (contol condition). Every repetition condition was presented with a lag of 2, 4 or 6 intervening items. Thus, each subject received both types (compound and complex) of high and low frequency words using all four repetition conditions and all three lag conditions.

To counterbalance possible item effects, four separate lists were constructed that counterbalanced the four repetition conditions across the four types of items (real compound words; real complex words; pseudo-compound words; pseudo-complex words). (For the first 2 of these lists, see Appendix G). Finally, to balance any possible order effects, two orders were prepared for each of the four lists. Both orders for the first list are contained in Appendix H.

At least part of the need to counterbalance carefully between subjects was because the compound words was chosen such that the first 12 were high frequency, the second 12 low frequency. The first 6 items in both these groups are internal item frequency consistent with overall frequency (i.e,, a high frequency word with both units high frequency). The second 6 items in each group were internal frequency mixed, where the frequency of one of the subunits does not match the overall frequency.

Therefore, stimulus type (word vs. nonword), construction (compound vs. complex), frequency, internal subunit consistency, repetition and lag are all within-subject factors, while item order-of-repetition and stimulus sequence thus, by definition, internal subunit consistency are counterbalancing between-subject factors.

The subjects were all volunteers from the University of Alberta undergraduate subject pool. There were a total of 36 subjects in Experiment 3 selected on the basis of being right-hand dominant.

Apparatus and procedure. A total of 192 items was presented to each subject in a lexical decision task. Half the items were real English words, either compound words, e.g., BEDROOM or subunit words, e.g., MISTY, or morphologically complex words, e.g, QUESTION. Half the items were pseudo-words (e.g., HOOKCHERRY, or THOUSFECT) or nonwords formed by protions of other stimuli (e.g., ELEC).

The equipment and procedures were identical to those used in Experiment 2, with one exception. For half the subjects, the Right response key indicated a real English word. For the other subjects, the Right response key indicated a nonword item.

Subjects were again instructed to respond as quickly as possible, and not to worry about occassional errors. Subjects received 48 practice trials prior to the test trials. The data from four subjects was excluded from analysis because more than one-third of their reaction times exceeded 3 seconds.

RESULTS

The data were analyzed similar to Experiments 1 and 2. The raw data were collapsed according to repetition condition (i.e., whole word repeated, first unit, second unit, no repetition) thus confounding the effects of individual items and lag per repetition condition. The mean of all correct reaction times within each stimulus summed over repetition condition was computed for each subject. Multiple analyses of variance were performed using both reaction time (RT) and errors as dependent measures. The data were analyzed in a wihin-subject design with repeated measures; no analyses were performed on stimulus sequences. Cells with no correct responses were treated as missing data in the RT analyses.

Reaction Time Data. The reaction time data for Experiment 3 are shown in Table 3. The overall analysis was a 2 (word, nonword) X 2 (compound, complex) X 2 (high, low frequency) X 4 (repetition conditions design.

Words were responded to significantly faster than nonword, F(1,31)=30.4, p<.001. There was an overall effect of repetition for both word and nonwords, F(3,93)=11.2, p<.001, when all repetition conditions are examined. A separate analysis was performed for the effect of whole unit repetition (whole vs. non-repeated) for words and nonwords, compound and complex, and both high and low frequency.

These results again indicate the significant difference between words and nonwords entirely consistent with the existing literature (e.g., Chastain, 1986). Although there is no overall effect for word

Table 3: Reaction time (in ms) for the Repetition Task of Experiment 3

	WORDS				NONWORDS			
	Compound		Complex		Compound		Complex	
	High	Low	High	Low	High	Low	High	Low
REPETITION								
Control	707	824	714	866	995	942	840	930
Whole	715	800	706	832	870	835	841	902
First	719	908	699	870	1074	922	935	907
Second	737	806	719	891	1088	999	883	921

type (compound vs. complex), F(1,27)=0.2, p<.64, word type interacted with the word-nonword variable, F(1,27)=7.6, p<.01, and with the frequency variable, F(1,27)=11.7, p<.002. High frequency items (regardless whether words or nonwords) were responded to 63 ms faster than low frequency stimuli, while the global effect of repetition enhanced response times approximately 41 ms, F(1,27)=6.5, p<.02. In examining the interaction terms, the four-way interaction is not significant, F(1,27)=0.3, p<.59, however the two three-way interactions are significant.

Word-nonword X type X repetition, F(1,27)=4.6, p<.04, shows the different effects of stimulus type on repetition. Compound words only benefit 11 ms from repetition; complex words benefit 32 ms. Compound nonwords benefit 105 ms while complex nonwords only benefit 12 ms.

Word-nonword X frequency X repetition, F(1,27)=5.6, p<.03, shows the different effects of frequency on repetition. High frequency words benefit only 3 ms with repetition, while low frequency words benefit 41 ms. High frequency nonwords benefit 92 ms while the low frequency nonwords benefit 24 ms.

'Wordedness' thus interacts across most variables. Thus, the word stimuli were analyzed separately from the nonword foils.

An essential issue in this experiment was to demonstrate differences between compound and complex words revealed through whole word repetition. A second issue concerned the processing of subunits enroute whole word recognition. Thus, further analyses were directed towards these two ends. For words and also for nonwords, the data were analyzed using three designs. First, to examine whole word effects, the design was 2 (compound, complex) X 2 (high, low) X 2 (whole word vs. not repeated). Next, comparing subunit repetition to whole word repetition, the analysis was 2 (compound, complex) X 2 (high, low) X 3 (whole word vs first unit vs second unit repetition). Finally, to examine subunit repetition as compare to the non-repeated condition, the design was a 2 (compound, complex) X 2 (high, low) X 3 (first unit vs second unit vs not repeated). These designs were applied to RT data and also to error data (shown in Table 4).

Words: The first analysis, whole word repetition using RT, revealed no main effect for type (compound, complex), $F(1,28)=1.8$, $p<.19$. There was a main effect for frequency, $F(1,28)=37.8$, $p<.001$, with high frequency words being responded to greater than 130 ms faster. Unexpectedly, there was no effect of repetition, $F(1,28)<1.0$, and none of the other effects or interactions were significant, all had $F(1,28)<2.0$.

Table 4: Errors (in percent) for the Repetition Task of Experiment 3

	WORDS				NONWORDS			
	Compound		Complex		Compound		Complex	
	High	Low	High	Low	High	Low	High	Low
REPETITION								
Control	1.1	4.8	1.1	9.3	10.9	3.2	4.9	1.2
Whole	1.1	4.8	0.0	6.3	4.3	3.2	1.1	5.3
First	0.0	6.4	2.1	10.9	12.7	12.6	5.3	2.1
Second	4.3	6.3	0.0	11.7	15.9	4.25	1.1	4.25

The same analysis applied to errors revealed only a main effect of frequency, F(1,28)=9.5, p<.005, high frequency items had a mean error rate of approximately 0.9% wile low frequency items had a mean error rate of approximately 6.1%. None of the remaining F values exceeded 1.5.

The subunit X whole word repetition analysis also showed no main effect for type, F(1,30)=0.5, p<.49. Similar to the first analysis, there was a strong main effect of frequency, F(1,30)=60.0, p<.001. Although there was no main effect for repetition, F(2,60)=2.3, p=.11, there were two significant 2-way interactions: the type variable interacted with the repetition variable, F(2,60)=2.7, p<.07, and the frequency variable also interacted with the repetition variable, F(2,60)=2.7, p<.07. Neither of the other interactions were significant; F values were less than 1.5.

In this analysis high frequency items were responded to approximately 140 ms faster than low frequency items. For compound words, first unit repetition slowed responding by 60 ms while second unit repetition had less effect (12 ms slower). Complex words were less affected by subunit repetition and the pattern was reversed: first unit repetition slowed responding approximately 18 ms while second unit repetition slowed responding by 40 ms approximately.

Overall, high frequency words showed little effect of subunit repetition (3 ms slower with first unit repetition and 15 ms slower with second unit repetition). However, low frequency words showed marked slowing with subunit repetition (approximately 78 ms slowing with first unit repetition and 37 ms slowing with second unit repetition.

The comparable error rate analysis illustrated a main effect of frequency, F(1,30)=28.5, p<.001, and a significant interaction between the type variable and frequency, F(1,30)=6.0, p<.02. These effects were in the same direction as the RT data. None of the other effects were significant; all F's were less than 1.0.

The third analysis, <u>subunit repetition compared to non-repeated condition</u>, may allow greater understanding of effects of subunit repetition, per se. The effects were comparable to those seen in the second analysis: a main effect for frequency, F(1,27)=44, p<.001, and the interaction between the type variable and frequency, F(1,27)=2.9, p<.10, approached significance. The only other significant effect was a 2-way interaction: frequency X repetition, F(2,54)=4.5, p<.01.

Compound words benefited 120 ms from high versus low frequency, while complex words benefited approximately 175 ms. As with the immediately preceding analysis, there was a differential effect of subunit repetition on high and low frequency words: repetition had little effect on high frequency words but a substantial effect on low frequency words.

The corresponding error rate analysis illustrated comparable effects: a main effect of frequency, F(1,27)=25.1 p<.001, and an interaction between the type variable and frequency, F(1,27)=5.6, p<.03. None of the remaining analysis showed significant effects.

Nonwords. Understanding these repetition effects in the compound words may be easier if we examine the nonword data. The same three analyses used for words were also used for the nonword data. The first analysis, whole nonword repetition using RT, illustrated a main effect for stimulus type (compound, complex), F(1,30)=9.4, p<.05, where pseudo-compound stimuli required approximately 37 ms longer to reject than did pseudo-complex stimuli. Although there was no main effect for frequency, F(1,30)<2, the interaction between type and frequency was significant, F(1,30)=8.1, p<.008. High frequency pseudo-compound stimuli took approximately 44 ms longer to reject as nonwords compared to their low frequency counterparts. For the pseudo-complex foils, the effect was reversed: high frequency pseudo-complex stimuli were rejected approximately 70 ms faster. As well, there was a significant effect of whole stimulus repetition,

$F(1,30)=20.1$, $p<.001$: repeated nonwords were successfully rejected approximately 67 ms faster than non-repeated stimuli. The interaction between type (compound, complex) and repetition was significant, $F(1,30)=$[illegible]$.1$, $p<.008$. Pseudo-compound nonwords benefited approximately 116 ms from repetition, while pseudo-complex nonwords benefited only approximately 18 ms. Neither of the other effects were significant in this analyis: the interactio[illegible]f frequency X repetition yielded $F(1,30)=2.8$, $p<.11$; [illegible]-way interacton yeilded $F(1,30)<.1.0$.

The corresponding error rate analysis showed only one effect: a significant interaction of frequency X repetition, $F(1,30)=4.2$, $p<.05$, which was in the same direction as the marginal effect quoted in the RT analysis.

The second analysis, subunit versus whole stimulus repetition, illustrated an expected main effect of frequency, $F(1,31)=8.5$, $p<.006$, plus the continued interaction of frequency with stimulus type, $F(1,31)=10.3$, $p<.003$. Frequency effects were the reverse of commonly occurring effects: high frequency nonword stimuli took approximately 40 ms longer to reject than their low frequency counterparts. Examining the interaction, we found effects similar to te first analysis. High frequency compound nonwords took approximately 100 ms longer than low frequency; high frequency complex nonwords benefited approximately 20 ms compared to the low frequency complex nonwords.

In keeping with the first analysis, there was a strong main effect of stimulus type, F(1,31)=26.7, p<.001, a strong main effect for repetition, F(1,31)=23.8, p<.001. The interaction of repetition with stimulus type was significant, F(1,31)=10.1, p<.001, as was the interaction of frequency with repetition, F(1,31)=3.4, p<.04. The 3-way interaction, F(1,31)<1.0, was not significant.

The corresponding error rate analysis shows comparable effects for stimulu type, F(1,31)=24.4, p<.001, for the interaction betwen type and frequency, F(2,62)=5.1, p<.03, for repetition, F(1,31)=6.1, p<.004, and for the interaction between type and repetition, F(2,62)=3.8, p<.03. The 3-way interaction was significant, F(2,62)=2.5, p<.09, comparable to the similar 3-way interaction seen in the second word analysis.

For high frequency compound nonwords, repetition of the first subunit provided approximately 8% more errors, second unit reptition approximately 11% more errors compared to whole stimulus repetition. The direction of results is similar for low frequency pseudo-compound stimuli: first unit repetition resulted in approximately 7% more errors, second unit repetition approximately 1% more errors. With the complex nonwords, the pattern of results was different. Repeating the first subunit in the high frequency pseudo-complex stimuli resulted in increased errors approximately 5%; repeating the second subunit had no effect on errors. For low frequency complex nonwords, repetition of the first subunit reduced errors by approximately 3%. Repetition of the second subunit reduced error by approximately 1%. Thus, the low frequency pseudo-compound stimuli behave similarly to the high frequency pseudo-complex stimuli.

The third nonword analysis was *subunit versus non-repetition*, to examine the subunit repetition effect, per se. The results were very similar to the immediately preceding analysis. The significant main effects were for type, $F(1,30)=37.6$, $p<.001$, and frequency, $F(1,30)=8.8$, $p<.006$; while repetition, $F(2,60)<2.0$ was not significant. The interaction of type and frequency was significant, $F(1,30)=10.4$, $p<.003$. The interaction of type and repetition was significant, $F(2,60)=2.8$, $p<.07$, as was the interaction of frequency and repetition, $F(2,60)=4.4$, $p<.02$.

Examining Table 5, we see that pseudo-compound stimuli were much more affected by repetition than were pseudo-complex stimuli. For these nonword stimuli

Table 5: Repetition effects for NONWORDS:
Reaction Times (RTs; in ms)
and Errors (%)

TYPE	REPETITION EFFECT		
	Whole	First	Second
High Compound	+115 ms (+5.4%)	-79 ms (-2.1%)	-87 ms (-6.6%)
Low Compound	+107 ms (+1.1%)	+20 ms (-6.6%)	-57 ms (0%)
High Complex	-1 ms (+3.2%)	+6 ms (-1.1%)	-43 ms (+3.2%)
Low Complex	+28 ms (-3.8%)	+23 ms (0%)	+9 ms (-2.2%)

Note. (+) indicates a benefit from repetition, and
(-) indicates slower responding

(regardless of type), repetition affected low frequency stimuli much less than high frequency nonwords. The 3-way interaction was not significant, F(2,60)=1.6, p<.22.

The corresponding error rate analysis showed main effects of type, F(1,30)=19.3, p<.001, frequency, F(1,30)=4.1, p<.05, and the interaction of type with frequency, F(1,30)=3.1, p<.08. These effects were in the same direction as the RT analysis. Of the remaining analysis, only the 3-way interaction was significant, F(2,60)=3.5, p<.04. The results indicated that high and low frequency, compound and complex words were affected differently by subunit repetition. This suggests a speed-accuracy trade-off that may have reduced differences in RT data such that the RT effects were reduced, or a real RT effect m;ay have been masked.

Examining the error data, we saw that high frequency compound nonwords were decremented approximately 2% by first unit repetition and approximately 7% by second unit repetition. Low frequency compound nonwords were decremented approximately 6% by first unit repetition but were unaffected by second unit repetition. High frequency pseudo-complex stimuli were decremented approximately 1% by first unit repetition and benefited approximately 3% by second unit repetition. Low frequency pseudo-complex stimuli were unaffected by first unit repetition but were decremented approximately 2% by second unit repetition.

Finally, a post-hoc stimulus analysis was done. The important subunit effects shown in this excperiment were related to the use of very specific stimulus materials (i.e., compound words). Examination of stimulus effects might be theoretically interesting in terms of which stimuli showed the effects and which did not. Unfortunately, the experimental design was such that no subject saw an individual stimulus under all four conditions: no repetition, whole stimulus repetition, first unit repetition, second unit repetition. Thus, the stimulus analysis became a between-subject design: the four orders were analyzed separately and the data entered into a 196 (number of stimuli) by 4 (number of conditions) matrix. No single stimulus was found that illustrated all of the repetition effects. Although unfortunate, this was not an unexpected finding as the between-subject design tends to obscure stimulus effects because the subject variance is usually higher than the stimulus variance.

DISCUSSION

Experiment 3 has provided data that suggests a difference between compound and complex words that have been matched in terms of length and frequency. The results can be best summarized as follows (see Table 6): consistent with the existing literature, high frequency words were responded to more quickly than low frequency words, and words were responded to more quickly than nonwords. Also, as predicted, subunit repetition affect compound words differently compared to complex words and high frequency differently than low frequency items.

There were two quite unexpected results. First, overall response times were much slower than expected: approximately 780 ms for words and 890 ms for nonwords. Second, the effect of whole word repetition was not significant.

Direct examination of that nonsignificant whole word repetition effect revealed a 23 ms benefit to all words with repetition. Direct examination of the individual cell means revealed: low frequency complex words benefited approximately 55 ms, high frequency complex words benefited approximately 8 ms, low frequency compound words were approximately 32 ms faster, and high frequency compound words actually lost about 8 ms with repetition. Overall, these results were not incompatible with expected, except for the high frequency compound words. It may be that the loss in power associated with the secondary analysis has failed to indicate what appears to be a real effect for most whole word repetition. However, the overall response times may mitigate against this. These unusual high RT's may indicate the unusual nature of the task demands. The experiment was designed to enhance and thus explore subunit repetition effects. In doing so, the implicit task demands associated with subunit repetition may have obliterated the expected whole word repetition effect and also prolonged overall response times.

The data have supported the idea that compound and complex words are different, and this difference has interacted with known frequency effects. Certainly, the expectation was that an obtained difference between compound and complex words would somehow be related to the presence of the defineable word subunits within the compound words.

For both word and nonword stimuli, the type of stimulus (compound versus complex) interacted with both frequency and repetition. The analysis of the error rates reveals that these differences are not generally due to a speed accuracy trade-off. The stimuli were all matched in terms of length and frequency. Therefore, the difference must be due, at least in part, to the presence of an undisputed supra-letter subunit (i.e., 'word') within the compound words.

It may be argued that the longer latencies with nonwords somehow invalidates any word-nonword comparisons. Certainly we know that nonwords are responded to more slowly than words (Forster and Chamber, 1973; Frederikson & Kroll, 1976). It is quite likely that pseudowords require the construction of their own phonetic code using grapheme-to-phoneme correspondence rules, wheras real words do not require such extensive processing (for review, see Marcel & Patterson, 1978; see also Rossmeissl & Theios, 1982). This may well apply to the complex nonword foils in this experiment, but, the compound nonwords are all constructed of real word subunits. Therefore, at least at the level of subunits, these lengthy grapheme-to-phoneme correspondence rules need not be applicable.

In some other cases (where phonologic factors were tightly controlled), it has been suggested that a purely orthographic (i.e., graphemic) check was sufficient to explain word-nonword differences (Taft, 1982). However, our pseudo-compound nonwords are, by definition, orthographically legal, and the pseudo-complex stimuli were also constructed with regard to English orthography. The application of such grapheme-grapheme rules might well explain the delay with some of our nonword items. However, in some cases, words and control nonwords require similar processing times (e.g., compound low frequency, first unit repeated: words 908 ms; nonwords 922). The consistent use of an orthographic check cannot have been used to successfully differentiate these stimuli as the RT's are almost identical. Thus, word-nonword comparisons may be valuable in this analysis.

In summary, this experiment was meant to both utilize and emphasize frequency effects. The results have confirmed that the procedure did that. As well, the procedure was designed to maximize subunit effects in both word and nonword stimuli using repetition. Again, the results have indicated strong subunit effects. In fact, the task may have concentrated on subunit repetition so much so that implicit task demands implicitly may have reduced whole word repetition effects, thus contributing to the unexpected lack of an effect for whole word repetition.

GENERAL DISCUSSION AND CONCLUSIONS

The major conclusion drawn from these three experiments is that compound words are processed differently than are the complex words. The word-splitting task of Experiment 1 showed a reverse frequency effect for compound words where the high frequency words were subject to longer latencies compared to low frequency words. Experiment 2 (lexical decision task) provided RT evidence for an interaction between whole word frequency and word type (compound vs complex). As well, the error rate analysis of Experiment 2 indicated an effect of the internal subunit frequencies in the processing of the whole compound words. Experiment 3 used repetition priming to illustrate the different effects of subunit repetition on compound versus complex words. In general, both compound words and nonwords were influenced much more by subunit repetition than were complex words or foils. Overall, the effect of subunit repetition was negative, and this was especially true for the low frequency compound words and all the compound nonwords.

The data used to support these conclusions consists of both reaction time and accuracy measures. The relationship between response latency and error rates (i.e., 'speed-accuracy' tradeoff) has been the focus of unresolved debate for some years (for review, see Posner

& Rogers, 1978; see also Brewer & Smith, 1984; Dosher, 1981; Grice & Spiker, 1979; McKay, 1982; Meyer, Smith & Wright, 1982; Swensson, 1972). These two measures are not necessarily synonomous. However, with relatively long durations, such as found in these three studies, both errors and reaction time seem to reflect similar processes (Posner & Roger, 1978; Santee & Egeth, 1982). In general, the two measures tend to complement each other in illustrating similar effects in the present research.

Experiments 1 and 2 showed compound words to be different than complex words. Experiment 3 replicated this finding and demonstrated a subunit repetition effect that was different for compound and complex words and nonwords. The Experiment 3 data are especially compelling because the words within each condition were frequency matched, the letter length of items within conditions was matched to within 2 percent, and the repeated subunits were determined empirically as well as conforming to dictionary defined, syllabic boundaries.

In both Experiments 1 and 3, response times were longer than anticipated; this was especially so in Experiment 3. This generalized increase in response times may be related to task demands. In Experiment 1, words were 'split' explicitly. In Experiment 3, the word 'splitting' was implicit in the task, but perhaps just as obvious in the RT data. In both experiments, the longer latencies argue that either more processing or different processes are involved compared to the traditional lexical decision task (Experiment 2). And, the increased time seems related to the appearance of distinctive subunits: in the first experiment via instructions; in Experiment 3 by presenting subunits prior to whole word recognition.

In all three experiments, the data point to differences between compound and complex words, and these differences are more obvious when subunit words are emphasized. The results indicate a processing difference in compound words and implies an effect for subunit words in whole word recognition that is not the case for word-fragments.

Experiment 3 examined the subunit effect most directly. The findings that are of most concern are the longer response times overall, the very obvious decrement in responding with first subunit repetition in low frequency compound words and the decrement associated with either subunit repetition in the high frequency compound nonwords, and finally the obvious benefit of whole item repetition for low frequency compound words and all compound nonwords.

However, the data indicate other effects that must be dealt with before the more important effects can be addressed. The subunit repetition data reveal a benefit with first subunit repetition to both high frequency complex and compound words, and also a rather bewildering array of variable amounts of both positive and negative subunit repetition priming effects, especially evident in all the complex nonwords and also the low frequency complex words.

This second finding may be related to the issue of Left-to-Right parsing in letter strings. For example, Taft (1980) bases his theory of BOSS on obligatory Left-to-Right parsing in words. However, Jordan (1986) showed that a 'BOSS' was active in lexical decision regardless of position, i.e., directionality was not obligatory in the parsing of letter strings. Perhaps, directionality is a strategic component that can be manipulated either through explicit or implicit task demands. If so, directionality would be completely confounded in Experiment 3. That is, first versus second subunit repetition was specifically confounded such that subjects had no way of knowing which subunit preceded which stimulus. These ideas may be directly testable. If directionality is under strategic control, then it is likely under very poor control in poor readers and under good control in good readers. So, a replication of Jordan (1986) with good versus poor readers should replicate his results with good readers and fail to replicate with poor readers.

The earlier of these issues concerns the beneficial effect of the first subunit repetition which is more marked with complex words but also seen in compound words. These data directly support Taft's (1980) 'BOSS' theory. However, this does not necessarily mean, as Taft would have us believe, that a pronounceable and orthographically legal word-fragment consistently acts as the only unit of entry in lexical access across all types of words: affixed, morphologically complex, and compound. There is no doubt that factors such as pronounceability, familiarity, and orthography have effects on feature integration in both words and nonwords (Prinzmetal, Treiman, & Rho, 1986; Prinzmetal & Wright, 1984; Rosson, 1983; Tanenhaus, Flanigan, & Seidenberg, 1980). In our data, however, repetition of subunit words (rather than word-fragments) had more profound and negative effects on whole word recognition.

The concerns of interest are therefore the data that indicate a decrement in responding with subunit repetition. This lower responding is more marked in compound than complex words, and more pronounced in low as opposed to high frequency words. Direct examination of Table 6 shows that the effect is mostly contained in an almost 100 ms decrement in responding with first unit

Table 6: Repetition effects for Words: Both Reaction Times (RTs; in ms) and error (%) data

TYPE	REPETITION EFFECTS		
	Whole	First	Second
High Compound	-8 ms (0%)	+4 ms (0%)	-22 ms (-4.9%)
Low Compound	+32 ms (0%)	-89 ms (-3.6%)	+6 ms (-2.4%)
High Complex	8 ms (1.2%)	+21 ms (+1.2%)	-2 ms (+1.2%)
Low Complex	+54 ms (+[illegible].5%)	+6 ms (0%)	-8 ms (-2.5%)

Note. (+) indicates a benefit from repetition and
(-) indicates a slower responding

repetition in the low frequency compound words. In nonwords (Table 5), the most substantial ef[illegible]is also with compound stimuli, again most substantially inhibitory.

Some authors have related this inhibition to other effects. For example, Forster and Chambers (1973) have suggested that low frequency words and orthographically legal nonwords are essentially equivalent. Taft and Forster (1976) demonstrated an unusual frequency effect. The compound nonwords in their data show a reverse frequency effect for the first word. The presence of a high frequency word in a compound nonword slowed performance compared to foils where the first word was low frequency (Taft & Forster, 1976). First subunit repetition in a low frequency compound word could result in a reverse frequency effect (i.e., inhibition) such as found in the Taft and Forster (1976) nonword data. At first glance, it appears as if we have effectively forced subjects to respond based on inappropriate subunit access. However, our subjects do not fail to discriminate between compound words and nonwords. In fact, Taft and Forster (1976) find a beneficial effect of first word frequency in low frequency compound real words. Our subjects respond with reaction times (to low frequency compound words) similar to the Taft and Forster (1976) nonword foils, but are then successful in discriminating word and nonword stimuli. Thus an explanation based on simple frequency effects is inadequate to explain these data. Nor is there an easy explanation of the interaction of frequency with repetition that determines responding.

Examining the overall subunit repetition effects, an immediately attractive notion concerns lexical access for subunit words plus lexical access for the whole word. Chumbley and Balota (1984) indicate that some of the effect in lexical decision is due to a decision task that follows lexical access (p. 601). There are a number of ways that this idea may be applied to our data. There may be multiple decisions enroute whole word recognition. If each subunit word is processed as a word enroute whole compound word recognition, then each subunit as well as the whole word might activate a decision stage. Because there are not such specific word units in the complex words, there should be only one decision to the whole word. Thus, compound words should be consistently slower than complex words. In Experiment 3, some data are consistent with this idea. The compound nonword stimuli take aproximately 100 ms longer to reject than do complex nonwords. This effect holds up under all conditions. However, the compound high frequency words required the same processing time as the complex controls (715 ms versus 717 ms in the nonrepeated condition, appropriately). Low frequency compound words were responded to significantly faster than the comparable complex words (824 ms versus 886 ms in the nonrepeated condition, appropriately).

On the other hand, it may be that subunit processing has some more or less direct effect on whole word lexical decision. This effect might be related to lexical access but not requiring lexical decision per se. For example, lexical access within the nonwords may actually interfere with subsequent responding. Our nonword data support this notion: repetition of a subunit in a compound nonword usually slows responding to the whole word. However, subunit repetition in real words should always be beneficial. This is not so in our data as first subunit repetition in low frequency compound ords is markedly detrimental.

It does not appear a simple matter to apply the Chumbley and Balota (1984) decision rules across all stimuli in Experimental 3. With nonwords the data are entirely consistent with the notion of subunit words being accessed during processing, and that access influencing the whole word decision process in some way.

Another arguement would be to suggest that there is actually a two-stage discrimination process with compound words where increased frequency (or repetition) of subunits makes subsequent whole stimulus discrimination more difficult in some cases. The more difficult cases are those where words and nonwords are difficult to distinguish, as is the case with our low frequency compound words and both high and low frequency compound foils. The words are distinctive in having a unique lexical entry while the nonwords do not. However, in both cases there is a semantic interpretation that may arise from processing of the subunit words.

The syntactic and grammatical relationships between words can be very important in lexical decision (for review, see Bock, 1982). For example, Lukately, Kostic, Feldman and Truvey (1983) showed that the presence of appropriate prepositions speeded lexical decisions for subsequent nouns compared to inappropriate prepositions. Certainly within the sentence context, congruent words are processed more quickly and accurately than incongruous words (Fischler & Bloom, 1979, 1980; Stanovich & West, 1979, 1981). This effect is related to syntax and grammar as well as to the semantic characteristics of immediately neighboring words (Stanovich & West, 1983). Used alone, these syntactic and grammaric rules can not be used to explain our data. Our nonwords were carefully constructed to resemble real compound words both syntactically and grammartically.

The proposal then is that lexical access must somehow involve an interaction between (a) total frequency which includes orthographic familiarity, syntactic familiarity and also lexical frequency (both subunit and whole word) and (b) word meaning. The interactive-activation model (McClelland & Rumelhardt, 1981; Rumelhardt & McClelland, 1982) of word recognition allows for this type of processing: parallel processing both between elements and also across time. These general concepts have received verification from a number of sources.

For example, this type of interaction between elements in word perception has been used to explain the integration of physical features and context (Rueckl & Oden, 1986), as well as the interference effects between sequentially presented phonemes (Stemberger, Elman, & Haden, 1985). Miller (1983) has presented evidence suggesting parallel processing across time (i.e., synchronous processing), although he indicates that not all phases of stimulus recognition begin simultaneously. That is, response preparation begins only after some basic processes in stimulus recognition.

Some of our results mimic some of the data for digram frequency effects in words where high frequency digrams can actually slow performance on low frequency words (see Gernsbacher, 1984). This is similar to the effect of high frequency word in a compound p[illegible] previously cited by Taft (1976). In both cases, an interaction between whole word frequency and subunit frequency is evident. If this type of interaction is applied consistently, a low frequency compound nonword composed of two high frequency subunit words should take much longer to reject than a control stimulus composed of two low frequency subunits. Our data are completely consistent with this idea. Our nonword compound items composed of high frequency subunits take significantly longer to reject as nonwords.

In this regard, it has been suggested that nonwords that are word-like are much more likly to activate lexical processes and thus are more difficult to reject (Lupker, 1984; Rubenstein, Lewis, & Rubenstein, 1971). This may represent some type of total familiarity score, similar to the Atkinson and Juola (1973) concept of familiarity. Familiarity for all the 'elements' of the item may make it more word-like: subunit frequencies (including digram, trigram, subunit words, etc.), orthographic structure, syntactic familiarity, etc. However, our data seem to indicate the possibility of two processes at work within lexical access. The first process concerns this total familiarity with the elements. The second process is related to the word-nonword distinction. This second process may be based on the availability of a semantic interpretation that could be applied to the letter string, and the subseqent examination of that semantic interpretation with regard to specific lexical entries.

For example, we know that semantic relatedness between words can enhance responding (for review, see Neely, 1977, and Schvaneveldt & McDonald, 1981). However, inappropriate semantic preparedness can interfere with subsequent responding (for review, see West & Stanovich, 1982). In general, the assumption has been that the "processes that select word meanings and integrate access entries do not guide lexical access but instead operate after lexical access" (West & Stanovich, 1982, p. 398).

This seems to be the case with our nonwords. The 'high frequency compound nonwords' have a high index of familiarity as well as a semantic interpretation that is probably available on the basis of lexical access occurring for the subunit words. The whole stimulus is then extremely difficult to reject as a nonword. Repetition of the whole stimulus allows subsequent examination of the semantic interpretation to be more rapid, and thus, the nonword is more rapidly rejected. This whole item repetition effect is thus analogous to the perceptual fluency hypothesis of Jacoby and his colleagues (e.g. Johnston, Dark, & Jacoby, 1985). That is, prior presentation of an item makes that item easier to perceive (i.e., faster) when presented again.

This same perceptual fluency works in a negative way with subunit repetition. In the same high frequency compound nonwords, prior presentation of the subunits provides for an increase in the familiarity index without any chance of directly examining the semantic interpretation of the compound. Thus, subunit repetition makes subsequent responding more difficult by increasing the total familiarity index, (i.e., increases the factors that mitigate toward inappropriate lexical access for the whole stimulus) without a corresponding effect on whole stimulus responding.

A similar case can be made for the low frequency compound words and nonwords. Subunit repetition increases the familiarity index but does not allow direct examination of the semantic interpretation. Again, whole stimulus repetition aids subsequent responding by allowing prior examination of the semantic variable. Subsequent examination of the semantics in regards to specific lexical entries is thus facilitated. However, with high frequency compound words, the semantic variable is easily compared to an actual lexical entry as that lexical entry is itself high frequency. Here, the entire word has high perceptual fluency because of numerous prior exposures (i.e., high frequency). Thus, whole word repetition should have little effect on subsequent responding; neither should subunit repetition.

Finally, the overall longer latencies argue that there is another process operating prior to whole word lexical access. The process is more obvious with compound words and nonwords. However, the longer latencies encountered in Experiments 1 and 3 also involve complex words and nonwords. Perhaps semantic systems are activated prior to the whole stimulus lexical decision. This notion has received independent verification (Herdman & Dobbs, 1984), and the effects seem related to task demands. Perhaps this suggests that changes to the stimulus items and thus changes in task demands in Experiment 3 could reduce the effects markedly. For example, elimination of the low frequency compound words and nonwords would allow subjects to examine the compound words on the basis of a comparison involving only the very accessible high frequency whole words. The compound nonwords (all high frequency now) should become less affected by subunit repetition, and the overall latencies should drop.

In fact, there is no associative strength between the subunits in the compound nonwords of Experiment 3. If semantic issues are important in determining lexical decision for the whole stimulus, then altering the semantic relationship between the subunits could have powerful effects. For example, Experiment 3 could be replicated using compound nonwords constructed such that the associative strength between the subunits was high. The expectation is that there should be either an increase in response latencies or an increase in error rates to accompany this more difficult semantic comparison.

The data presented here have been used to argue that lexical access is an interactive process. The initial analysis of a subunit word causes semantic activation, similar to the activation of words that are presented in sentences (for example, see Oden & Spira, 1983). That is, the individual words are processed but resolution is dependent on a more global context. In sentence experiments, the more global context is the sentence; in these experiments, it is the whole word. Thus, as stimulus analysis progresses, word identification is accomplished with specific reference to meaning (Marslen, Wilson, & Welsh, 1978; Sanocki, Goldman, Cook, Epstein, and Oden, 1985). Thus, in compound words, subunit words may affect whole stimulus recognition depending on the total familiarity of the stimulus and the availability of a semantic interpretation as well as the subsequent examination of that interpretation.

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APPENDIX A

Practice Items

PRACTICE ITEMS

Compound Words

hollywood
helpless
taxpayers
daytime
wildlife
classroom
halfway
overnight
sunlight
broadcast
network
northeast
payroll
viewpoint
commonplace
turnpike
meanwhile
skywave
widespread
nowhere
folklore
weekend
cocktail
workshop

Complex Words

happiness
heritage
telegraph
cottage
theology
commented
favored
objection
throwing
chemistry
muscular
prolonged
possess
typically
connections
touching
presently
slipped
constitute
lighted
formerly
veteran
breaking
specimen

APPENDIX B

Experimental Materials

COMPOUND WORDS

High Frequency

Consistent

ONTO
NEWSPAPER
BASEBALL
BEDROOM
SUNDAY
CHAIRMAN
SOMETHING
OUTSIDE
ANYONE
UNDERSTAND
MOREOVER
BACKGROUND

Mixed

THEREFORE
AIRCRAFT
CHILDHOOD
AFTERNOON
HIMSELF
KNOWLEDGE
FORWARD
OTHERWISE
HEADQUARTERS
BEHIND
RAILROAD
MESSAGE

Low Frequency

Consistent

FROSTBITE
GRAPEVINE
PUMPKIN
PEGBOARD
LOGJAM
CRANKSHAFT
CRABAPPLE
HOOKWORM
PIGPEN
CHOKECHERRY
TOADSTOOL
SHOELACE

Mixed

BROADBEAN
EYEBROW
SNOWPLOW
TABLESPOON
WATERSHED
DOORKNOB
STONEWARE
DOWNPOUR
DUSTBIN
SKYSCRAPER
PAWNSHOP
WRISTWATCH

COMPLEX CONTROL WORDS

High Frequency

NOSE
EMPLOYEES
ENTRANCE
CENTERS
ACTUAL
ANSWERED
PRESIDENT
MORNING
SHOWED
POPULATION
GREATEST
STATEMENTS

EDUCATION
EXCHANGE
BRILLIANT
AGREEMENT
AGAINST.
CHRISTIAN
LETTERS
FINANCIAL
SIGNIFICANCE
MAKING
OCCASION
LOCATED

Low Frequency

GALLANTRY
GRIEVANCE
PULSING
PENDULUM
LODGED
CRIMSONING
CRACKLING
HOLSTEIN
PICKER
CHRONICALLY
TITRATION
SHREDDER

BRITISHER
FATALLY
SOBRIETY
TECHNICIAN
VIOLINIST
DIVINELY
SUBSIDIES
DOUBTING
DWARFED
SLACKENING
PATENTED
XENOPHOBIA

APPENDIX C

Instructions to Subjects

SPEED INSTRUCTIONS

First of all, I would like you to relax. This experiment is not evaluative in any way. We're interested in the average performance across many people, rather than individual performance, consequently, your name will not be associated with your data; your data will be stored in a numbered file, like this (SHOW EXAMPLE).

In this experiment we are studying how people make decisions about the English language. In order to do this, I will present a number of strings of letters on the screen in front of you. Your task will be to decide whether each string of letters forms a real, Englis word, or whether the string of letters forms a nonword. The words are common enough words. this is not a vocabulary test.

Here is an example. The top letter set is a word (NORTH), while the lower one is a nonword (NJFXAK).

Once in a while, items will be repeated, so do not be surprized is you see the same items more than once. When a latter string appears on the screen, you are to decide "as quickly as possible" whether it si a word or a nonword. We will be measuring how quickly you can make each decision.

Here is how we will do it. In front of you are two response keys. The button to the LEFT/RIGHT indicates a "yes WORD" response, while the button to the RIGHT/LEFT indicates a negative "NONWORD" response. As each word appears, you are to indicate your decision by pressing one of the two response keys. use your right hand. If the letter string is a real English word, push the LEFT with the index finger of your dominant hand. when the presented item is NOT a word, push the RIGHT response button with your index finger. So, the one button always signals real, English words. The other button always indicates a nonword item. Also, during the experiment your hand should not leave the response box. Keep your fingers resting lightly on the box so that you will be ready to respond quickly.

Prior to the presentation of each letter string, a dot will appear on the screen in front of you. Keep your attention on this dot. It tells you where the item will appear. You will then hear a tone over the headphones. this is a warning signal and indicates that a letter string will appear in about half a second. Each letter string throughout the experiment will be preceded by a tone. When the letter string appears, decide as quickly as possible whether it is a word or not. If it is a word, press the LEFT ke;y as quickly as you can. If the word is not a word, press the RIGHT key as soon as possible. In each case, decide as quickly as possible. Treat the task as a reaction time task in which you are to make your decision and react as quickly as possible. Try to be accurate but do not worry if you make an occasional error. The rate at which the items are presented will be the same throughout the experiment. Again, each new trial will be signaled by the appearance of a dot which shows where the item will appear on the screen. Then a warning tone will come on and the item will appear. Do you have any questons?

We will go through 28 practice trials so that you can become familiar with the task. But first, practice pushing the keys so that you become familiar with how they feel.

OK, are you ready to start the practice trials? Please put the headphones on.

Which key is for words?
Which key is for nonwords?
Check R vs L keypress.

Following practice trials.....

OK, that was good. Do you have any questions about the task?

If there are no (other) questions, we will begin the real task. The task is set up exactly the same way as the practice task. There will be 168 items in this part of the task. It is very important for you to do your best on every trials. The procedure is exactly the same as on the practice trials. Remember that your hands should not leave the response keys. Make your decisions as fast as you can. Then react to press the appropriate key as soon as possible. Again, the one key indicates a real, English word; the other key indicates a nonword item.

OK - remember to treat the task as a reaction time task in which you are to make fast decisions and reach as quickly as possible.

Any questions?

Please put your headphones on; we are ready to begin.

APPENDIX D

Nonword Foils

NONWORD FOILS

ELIK
GILSOCHUA
JETAFLUC
PSUEMPO
KEVODI
VOMPLAFL
URKIORPUA
RUBAVOV
LIVODD
KEPOSMOPAU
WOBEKSYE
JEKNUMOPTI

YOVA
WEVOIPSUL
GOKSHUIL
CRIVACO
TAVOLV
DOPSHUEE
SYOOKSHOV
JOAVIFA
TUTIEG
BRIGELFEVI
TAKIDYSU
UEMPOCRIVA

NAKSIGRIKI
KIGLUNCK
ZETCAWNIC
FIVAMOBRL
WIMAPEF
AWECISISS
YEPIVOI
KIOMSYSYO
POBIMAFEPTAI
PURYOK
AYETOBEO
QUNOMOE

DEPAMORDUR
TRIGSULD
ECOLAMIVA
DUMSOPPIO
BOAVARI
FRAGULOYE
VODAVAC
OLABRAVOE
SAOMURTOEOCA
IOABUB
GULDEIMA
JEFAYOT

ZELKILYSH
ZETAIFFIS
GOVAYEV
VOBRYE
PAGUNUPOMO
FRABOBAPO
DEKISIVA
HOKIPA
NURMAISAKID
SIOYEGLUA
ETACOVOO

QUABIMOSM
AUDEYOFTI
GAKNIKS
VOLIKS
UBISHOAMPA
JOCAIFAKI
ZUCEKIMS
ADUNUM
MAUTCHUCOKI
SCHIPSAMA
ZEMILAGU

JOKIRUABE
POVILIL
QUPAPRYO
JUMOPTILM
JUPOCEET
NOYIRYSHU
BIRGSAGL
PEPUBAU
DAUNKIPUGL
YEOYSHOM
SILDULYSUM

FAYIDOBI
GAUDDET
SAPEPUIP
SAIGILISO
CLOSWIDU
QUEWIMAPE
FAPLILKS
YOIMAPL
SAKECTODEV
TURTEOC
TUNOYECACI

APPENDIX E

Experiment 3: Stimulus Materials

COMPOUND

Word	Pseudo
1.NEWSPAPER	25.DEEPRANGE
2.BASEBALL	26.THINPOOL
3.BEDROOM	27.SEAFACE
4.CHAIRMAN	28.SWEETWAR
5.OUTSIDE	29.BOYDOOR
6.BACKGROUND	30.WORKISLAND
7.AIRCRAFT	31.CARSWEAT
8.AFTERNOON	32.WORLDPACK
9.HIMSELF	33.NEWINCH
10.HEADQUARTERS	34.EVERCALENDAR
11.THEREFORE	35.WHILESTIR
12.OTHERWISE	36.ABOUTHOST
13.FROSTBITE	37.FRIEDBOLT
14.GRAPEVINE	38.MISYWORM
15.CRABAPPLE	39.HOOKCHERRY
16.TOADSTOOL	40.TACKSTAMP
17.CHOELACE	41.PINELAMB
18.CRANKSHAFT	42.CROAKGHOST
19.EYEBROW	43.GUNCOMB
20.SNOWPLOW	44.ROOFSAIL
21.TABLESPOON	45.VALUESNACK
22.DOORKNOB	46.FREELEAK
23.DOWNPOUR	47.LEFTHOSE
24.DUSTBIN	48.RAININN

COMPLEX

Word	Pseudo
49.PRACTICE	73.BEAUMANCE
50.QUESTION	74.REACMENT
51.CONTROL	75.RESBERS
52.STRUGGLED	76.STRUCARD
53.CENTURY	77.DEMLAGE
54.ELECTRONIC	78.PRIMIQUES
55.MILITARY	79.LANCIPLE
56.TECHNICAL	80.DAUGHTION
57.GENERAL	81.MEACHEN
58.RECOGNITION	82.DIFFCUSSION
59.SHOULDERS	83.NEIGHMALS
60.STANDARD	84.THOUSFECT
61.PHARMACY	85.TELEPERS
62.SURVEYED	86.STRATIDLY
63.DIAGNOSIS	87.CASACIBLY
64.THUNDERED	88.BUFFICALY
65.GORG[illegible]US	89.CANTCADE
66.BLASPHEMOUS	90.BLIZZALOES
67.VOLCANO	91.TESPISM
68.STIFFENS	92.CLUMLATS
69.THERMOSTAT	93.SHRIELOUPE
70.SPLINTER	94.CHEMARDS
71.BLOSSOMS	95.SWALIZED
72.QUANTUM	96.CESSARDS

SUBUNITS OR CONSTITUENT ITEMS

Real

97.NEWS
98.BASE
99.BED
100.CHAIR
101.OUT
102.BACK
103.AIR
104.AFTER
105.HIM
106.HEAD
107.THERE
108.OTHER
109.FROST
110.GRAPE
111.CRAB
112.TOAD
113.SHOE
114.CRANK
115.EYE
116.SNOW
117.TABLE
118.DOOR
119.DOWN
120.DUST
121.PAPER
122.BALL
123.ROOM
124.MAN
125.SIZE
126.GROUND
127.CRAFT
128.NOON
129.SELF
130.QUARTERS
131.FORE
132.WISE
133.BITE
134.VINE
135.APPLE
136.STOOL
137.LACE
138.SHAFT
139.BROW
140.PLOW
141.SPOON
142.KNOB
143.POUR
144.BIN

Pseudo

145.DEEP
146.THIN
147.SEA
148.SWEET
149.BOY
150.WORK
151.CAR
152.WORLD
153.NEW
154.EVER
155.WHILE
156.ABOUT
157.FRIED
158.MISTY
159.HOOK
160.TACK
161.PINE
162.CROAK
163.GUN
164.ROOF
165.VALUE
166.FREE
167.LEFT
168.RAIN
169.RANGE
170.POOL
171.FACE
172.WAR
173.DOOR
174.ISLAND
175.SWEAT
176.PACK
177.INCH
178.CALENDAR
179.STIR
180.MIST
181.BOLT
182.WORM
183.CHERRY
184.STAMP
185.LAMB
186.GHOST
187.COMB
188.SAIL
189.SNACK
190.LEAK
191.HOSE
192.IN

Real

193.PRAC
194.QUES
195.CON
196.STRUG
197.CEN
198.ELEC
199.MIL
200.TECH
201.GEN
202.RECOG
203.SHOUL
204.STAN
205.PHAR
206.SUR
207.DIAG
208.THUN
209.GOR
210.BLAS
211.VOL
212.STIF
213.THERMO
214.SPLIN
215.BLOS
216.QUAN
217.TICE
218.TION
219.TROL
220.GLED
221.TURY
222.TRONIC
223.ITARY
224.NICAL
225.ERAL
226.NITION
227.DERS
228.DARD
229.MACY
230.VEYED
231.NOSIS
232.DERED
233.GEOUS
234.PHEMOUS
235.CANO
236.FENS
237.STAT
238.TER
239.SOMS
240.TUM

Pseudo

241.BEAU
242.REAC
243.RES
244.STRUC
245.DEM
246.PRIM
247.LAN
248.DAUGH
249.MEA
250.DIFF
251.NEIGH
252.THOUS
253.TELE
254.S[illegible]RAT
255.CASA
256.BUFF
257.CANT
258.BLIZE
259.TES
260.CLUM
261.SHRIE
262.CHEM
263.SWAL
264.CESS
265.MANCE
266.MENT
267.BERS
268.ARD
269.LAGE
270.NIQUES
271.CIPLE
272.TION
273.CHEN
274.CUSSION
275.MALS
276.FECT
277.PERS
278.IDLY
279.CILBY
280.ICALY
281.CADE
282.ALOES
283.PISM
284.LATS
285.LOUPE
286.ARDS
287.IZED
288.ARS

APPENDIX F

Percent Consensus for Stimuli

COMPOUND

Word		Pseudo	
1. NEWSPAPER	100%	25. DEEPRANGE	93.7%
2. BASEBALL	100%	26. THINPOOL	100%
3. BEDROOM	100%	27. SEAFACE	100%
4. CHAIRMAN	100%	28. SWEETWAR	100%
5. OUTSIDE	100%	29. BOYDOOR	100%
6. BACKGROUND	100%	30. WORKISLAND	100%
7. AIRCRAFT	100%	31. CARSWEAT	100%
8. AFTERNOON	100%	32. WORLDPACK	100%
9. HIMSELF	100%	33. NEWINCH	93.7%
10. HEADQUARTERS	100%	34. EVERCALENDAR	100%
11. THEREFORE	100%	35. WHILESTIR	100%
12. OTHERWISE	100%	36. ABOUTHOST	100%
13. FROSTBITE	100%	37. FRIEDBOLT	100%
14. GRAPEVINE	100%	38. MISTYWORM	100%
15. CRABAPPLE	100%	39. HOOKCHERRY	100%
16. TOADSTOOL	100%	40. TACKSTAMP	100%
17. CHOELACE	100%	41. PINELAME	100%
18. CRANKSHAFT	100%	42. CROAKGHOST	100%
19. EYEBROW	100%	43. GUNCOMB	100%
20. SNOWPLOW	100%	44. ROOFSAIL	100%
21. TABLESPOON	100%	45. VALUESNACK	100%
22. DOORKNOB	100%	46. FREB	100%
23. DOWNPOUR	100%	47. LEFTHOSE	100%
24. DUSTBIN	100%	48. RAININN	100%

COMPLEX

Word		Pseudo	
49. PRACTICE	81.2%	73. BEAUMANCE	100%
50. QUESTION	75.0%	74. REACMENT	100%
51. CONTROL	100%	75. RESBERS	100%
52. STRUGGLED	81.2%	76. STRUCARD	100%
53. CENTURY	100%	77. DEMLAGE	100%
54. ELECTRONIC	75.0%	78. PRINIQUES	100%
55. MILITARY	75.0%	79. LANCIPLE	100%
56. TECHNICAL	93.7%	80. DAUGHTON	93.7%
57. GENERAL	100%	81. MEACHEN	100%
58. RECOGNITION	81.2%	82. DIFFCUSSION	87.5%
59. SHOULDERS	68.7%	83. NEIGHMALS	100%
60. STANDARD	81.2%	84. THOUSFECT	100%
61. PHARMACY	68.7%	85. TELEPERS	100%
62. SURVEYED	93.7%	86. STRATIDLY	93.7%
63. DIAGNOSIS	81.2%	87. CASCIBLY	87.5%
64. THUNDERED	68.7%	88. BUFFICALY	68.7%
65. GORGEOUS	75.0%	89. CANTCADE	100%
66. BLASPHEMOUS	87.5%	90. BLIZZALOES	87.5%
67. VOLCANO	93.7%	91. TESPISM	93.7%
68. STIFFENS	75.0%	92. CLUMLATS	100%
69. THERMOSTAT	100%	93. SHRIELOUPE	93.7%
70. SPLINTER	93.7%	94. CHEMARDS	100%
71. BLOSSOMS	93.7%	95. SWALIZED	87.5%
72. QUANTUM	100%	96. CESSADS	87.5%

APPENDIX G

Counterbalanced Lists of Repetition Conditions

Group	Stimulus Type	Repeated Portion Whole	First	Second	Non-repeated
1	Compound High	1-3	4-6	7-9	10-12
	Compound Low	13-15	16-18	19-21	22-24
	NW Compound High	25-27	28-30	31-33	34-36
	NW Compound Low	37-39	40-42	43-45	46-48
	Complex High	49-51	52-54	55-57	58-60
	Complex Low	61-63	64-66	67-69	70-72
	NW Complex High	73-75	76-78	79-81	82-84
	NW Complex Low	85-87	88-90	91-93	94-96
2	Compound High	4-6	7-9	10-12	1-3
	Compound Low	16-18	19-21	22-24	13-15
	NW Compound High	28-30	31-33	34-36	25-27
	NW Compound Low	40-42	43-45	46-48	37-39
	Complex High	52-54	55-57	58-60	49-51
	Complex Low	64-66	67-69	70-72	61-63
	NW Complex High	76-78	79-81	82-84	73-75
	NW Complex Low	88-90	91-93	94-96	85-87
3	Compound High	7-9	10-12	1-3	4-6
	Compound Low	19-21	22-24	.....etc.	
4	Compound High	10-12	1-3	4-6	7-9
	Compound Low	22-24	13-15	.....etc.	

Note. High, Low: refers to high and low frequency
NW: refers to nonword

APPENDIX H

Master Order for List One

ORDER A = PAGE A + PAGE B
ORDER B = PAGE B + PAGE A

This is a two part master order for List One. Each order was comprised of this master order in different sequences. Order A was Page A followed by Page B. Order B was Page B followed by Page A. Both orders had a total of 168 items.

PAGE A

#	item	#	item	#	item	#	item
1	1	25	4	49	187	73	49
2	160	26	76	50	58	74	12
3	245	27	51	51	78	75	50
4	1	28	101	52	43	76	39
5	40	29	80	53	8	77	38
6	2	30	10	54	162	78	84
7	74	31	224	55	82	79	223
8	77	32	189	56	129	80	50
9	225	33	5	57	197	81	196
10	75	34	37	58	273	83	55
11	2	35	102	59	198	83	39
12	74	36	56	60	59	84	52
13	46	37	37	61	42		
14	3	38	271	62	53		
15	73	39	45	63	9		
16	57	40	188	64	161		
17	75	41	79	65	81		
18	73	42	6	66	54		
19	47	43	127	67	11		
20	51	44	246	68	60		
21	3	45	44	69	41		
22	100	46	7	70	49		
23	244	47	48	71	83		
24	272	48	128	72	38		

PAGE B

#	item	#	item	#	item	#	item
1	61	25	64	49	30	73	62
2	15	26	283	50	65	74	26
3	85	27	33	51	21	75	236
4	61	28	176	52	149	76	71
5	34	29	91	53	93	77	86
6	85	30	18	54	66	78	62
7	35	31	13	55	22	79	26
8	63	32	258	56	87	80	68
9	15	33	32	57	29	81	25
10	112	34	13	58	148	82	86
11	256	35	94	59	237	83	72
12	257	36	140	60	95	84	25
13	16	37	175	61	28		
14	88	38	70	62	23		
15	63	39	90	63	87		
16	113	40	31	64	27		
17	89	41	20	65	13		
18	36	42	150	66	69		
19	284	43	14	67	235		
20	177	44	141	68	13		
21	17	45	209	69	96		
22	208	46	285	70	67		
23	114	47	210	71	27		
24	92	48	14	72	24		

APPENDIX I

Machine Language Computer Program to Present Stimuli and Obtain Reaction Time and Accuracy Data for Two Subjects (6502 chip)

This program is an example of (Gillese Files). J:

```
GRAPHDRIVER.Z
GET RNDORDRLEX1 =5500       ;GET RANDOM ORDER
FILL 0000 001F 00           ;ZERO PAGE ZERO FOR SETUP
SET 0002 = 01               ;SETS NUMBER OF ITEMS IN
                             TARGET TO ONE
SET 000A = 01               ;SETS NUMBER OF SUBJECTS TO
                             ONE
FILL 6000 7FFF 00           ;ZEROS THE RT DATA FOR START
SET 8900 "SAVE ----ORDERA 6000 63D0" OD "SAVE ----ORDERA
7000 73D0" OD

SET REALITEMS.D =4000       ;GET ASCII TARGETS
REPEAT.C                    ;GET PRESENT PROGRAM AND RUN IT
DO LEXDEC.J                 ;RETURN TO THE MENU
```

```
;THIS PROGRAM IS CALLED REPEAT.A
;IT IS RUN BY  DO PRACTICE.J
;              DO (GILLESE FILES).J
;
;**********************************************************
;
;This program [illegible]sents a decision target.
;    The targ[illegible]can have one word with a maximum of 12
;    letters.
;
;The Experimenter enters the number of subjects and the
;    SUBJECT DATA FILE NAMES.  The data is automatically
;    stored in those files at the end of the task (the
;    last character of the file name is the number of
;    items in the targets and is entered automatically
;    by the computer).
;
;The duration of all intervals is in terms of the number
;    of vertical retraces, and hence must be a multiple
;    of 16 milliseconds.
;    These values are:
;      1. Duration of the fixation point (FIXDUR) is at
;         least $3E (62 x 16 = 992 msec), but not greater
;         than $BF (191 x 16 = 3056 msec.). This is
;         selected haphazardly by sampling a timer value
;         on each trial.
;      2. Duration of blank interval between the fixation
;         point and the target (FPDEL) = $02 (32 x 16
;         = 500 msec.)
;      3. Target remains on until the slowest subject
;         responds, or 4000 msec have elapsed. Thus, 4
;         seconds is the maximum RT that is allowed.
;      4. The inter trial interval is the duration of the
;         fixation point until the tone comes on which
;         varies beteen 992 and 3056 msec.
;    The data are AUTOMATICALLY saved at the end of the
;     presentation sequence throu SVC 13 located starting
;     at $8900.
;
;**********************************************************
;
;                        TABLES
;
;The ITEMS are stored in Memory Locations $4000 - $54FF.
; They are stored as follows:
;     ITEM NUMBER / TARGET (12 locations for the target
;      plus the first location that is not printed
;      It is the item number.
;      The next target follows immediately.
;
;The ORDER OF ITEM PRESENTATION is stored in Memory
;      Locations $5500 - $5FFF. The order is stored
```

```
;       with 8-BIT precision as follows:
;        One memory location for each item.

;   THE PROGRAM ENDS WHENEVER THE MSB OF THE ORDER IS $FF
;
;
;
;The RESPONSES for subject 1 are stored in memory
;     locations $6000 - $6FFF
;The RESPONSES for subject 2 are stored im memory
;     locations $7000 - $7FFF
;     The response data is stored as follows:
;
;       1. ITEM NUMBER (two memory locations; LSB, MSB of
;          the items number).
;
;       2. ACCURACY (one location where $01 = correct
;                                       $0F = error
;                                       $00 = too long
;
;       3. REACTION TIME (two locations where the first
;             is the number of millisecons, the second
;             is the number of 100 milliseconds.
;             There two must be added to get the RT.
;        The RT is 00 00 if the delay was TOO LONG
;
;*****************************************************


     ;*****************************
     ;   PSUEDO PROCESSOR ADDRESSES
     ;*****************************

SVCENB = $EE          ;ADDRESS OF SVC ENABLE FLAG
U0     = $B0          ;16-BIT ACCUMULATOR FOR PP
U1     = $B1          ;16-BIT PSEUDO-REGISTERS...
U2     = $B4
U3     = $B6
U4     = $B8
U5     = $BA
U6     = $BC
U7     = $BE          ;24 BIT REGISTER

     ;****************************
     ;      PAGE ZERO STORAGE
     ;****************************

RND    = $00          ;$00, 01 = STARTING ADDRESS
                      ;    OF RANDOM NUMBER TABLE
NUMTAR = $02          ;MEMORY LOCATION FOR NUMBER OF ITEMS
```

```
                        ;   IN TARGET
NUMLET  = $03           ;MEMORY LOCATION FOR COUNT OF NUMBER
                        ;   OF LETTERS PRINTED IN TARGET
                        ;   PRINT LOOP
PADD    = $04           ;ADDRESS OF CURRENT ITEM IS I[illegible]
                        ;$04, 05
RSUB1   = $06           ;RESPONSE DATA ADDRESS OF SUBJ. 1 IN
                        ;$06, 07
RSUB2   = $08           ;RESPONSE DATA ADDRESS OF SUBJ. 2 IN
                        ;$08, 09
NUMSUB  = $0A           ;MEMORY LOCATION FOR NUMBER OF
                        ;SUBJECTS
TYPES1  = $0B           ;SUBJ. 1 TYPE OF TARGET ($02=WORD:
                        ;$03=NONWORD)
TYPES2  = $0C           ;SUBJ. 2 TYPE OF TARGET ($08=WORD:
                        ;$0C=NONWORD)
TEMPR   = $0D           ;TEMPORARY STORE FOR RESPONSE (PORT B)
TIMEL   = $0E           ;NUMBER OF MSEC. OF RESPONSE TIME
                        ;COUNT
TIMEH   = $0F           ;NUMBER OF 100 MSEC. OF RESPONSE TIME
                        ;COUNT
ITNUM   = $12           ;ITEM NUMBER FOR TRIAL STORED IN
                        ;$2000, 2001
PRODUC  = $14           ;PRODUCT OF MULTIPLY TO OBTAIN ITEM
                        ;ADDRESS
ITEMS   = $16           ;$16, $17 = STARTING ADDRESS OF ITEMS
VCOMP   = $18           ;NUMBER OF VERTICAL RETRACE SIGNALS
                        ; DESIRED AS DURATION (#OF 16 MSEC)
COUNT   = $1A           ;COUNT OF THE NUMBER OF VERTICAL
                        ;RETRACES
SAVE    = $1C           ;ADDRESS OF VECTOR FOR SVC 13 (SAVE
                        ; DATA) $1C = $00; $1D = $89
NFILE   = $1E           ;COUNT OF INPUT FOR SVC 13 (SUBJECT
                        ; NAME FOR SAVING DATA FILES
STARTB  = $1F           ;COUNT TO SEE IF BOTH SUBJECTS HAVE
                        ; PRESSED THE START BUTTON
NLET    = $20           ;NUMBER OF LETTERS OF THE TARGET
TCNT    = $21           ;NUMBER OF LETTERS OF THE TARGET / 2
CENTER  = $22           ;COLUMN # FOR STARTING TO DRAW THE
                        ; TARGET OR MASK
                ;***************************
                ;               EQUATES
                ;***************************
FIXDUR  = $3E           ;MINIMUM DURATION OF FIXATION
                        ; POINT (# OF 16 MSEC)
FIDEL   = $20           ;FIXATION-TARGET DELAY (16*32=512
                        ; MSEC)
NTAR    = $01           ;NUMBER OF ITEMS IN TARGET (IF MORE
                        ; THAN ONE ITEM IN TARGET, MULTIPLIER
                        ; OF CALADD SUB MUST BE CHANGED: +11
                        ; FOR EACH ADDITIONAL ITEM.)
INTV    = $00           ;DEFINES $3000 AS THE ADDRESS FOR
```

```
INTV1  = $30           ; THE VERTICAL RETRACE INTERRUPT
                       ; SERVICE ROUTINE
INTR   = $20           ;DEFINES $3020 AS THE ADDRESS FOR THE
INTR1  = $30           ; VERTICAL RETRACE INTERRRUPT SERVICE
                       ; ROUTINE
TARSIZ = $09           ;NUMBER OF LETTERS IN THE TARGET
                       ; (DECIMAL 9)
TONEON = $32           ;NUMBER OF VERTICAL RETRACE COUNTS
                       ; THAT TONE IS ON
             ;**********************************
             ;         SYSTEM VIA 1
             ;**********************************
SYS1B  = $BFE0         ;PORT B SYS VIA 1; PB5 = DISPLAY
                       ;ENABLE
             ;**********************************
             ;          SYSTEM VIA 2
             ;**********************************

SYS2BV = $BFF0         ;PORT B SYS VIA 2; BIT 1 = TOP VIDEO
                       ; OUTPUT
SYS2A  = $BFF1         ;PORT A SYS VIA 2
SYS2BD = $BFF2         ;PORT B DDR VIA2; BITS 0 AND 1 =
                       ; OUTPUT FOR THE VIDEO
ACR2   = $BFFB         ;ACR SYS VIA 2
PCR2   = $BFFC         ;PCR SYS VIA 2 (CA1=VIDEO RETRACE
                       ; SIGNAL)
IFR2   = $BFFD         ;IFR SYS VIA 2
IER2   = $BFFE         ;IER SYS VIA 2
          ;*********************
          ;      USER VIA 0
          ;*********************
; NOT USED
          ;*********************
          ;      USER VIA 1
          ;*********************
U1PB   = $BEE0         ;PORT B: BITS 0-6 = INPUT
                       ;BIT 7 = OUTPUT
U1PA   = $BEE1         ;RANDOM NUMBER GENERATOR INPUT
UDDRB1 = $BEE2         ;DDRB: BITS 0-6 INPUT, BIT 7 = OUTPUT
UDDRA1 = $BEE3         ;DDRA: ALL INPUT FOR THE RND NUMBER
                       ; INPUT
TIMER1L= $BEE4         ;USER VIA 1 TIMER 1 LOW
TIMER1H= $BEE5         ;USER VIA 1 TIMER 1 HIGH
U1ACR  = $BEEB         ;ACR USER VIA 1
U1PCR  = $BEEC         ; PCR USER VIA 1
U1IFR  = $BEED         ;IFR USER VIA 1
U1IER  = $BEEE         ;IER USER VIA 1

GMODE  = $020A         ;GMODE ($80 = DRAW; $40 = ERASE)
XXHI   = $0207         ; HIGH BYTE OF XX COORDINATE
XXLO   = $0206         ;LOW BYTE OF XX COORDINATE
YYHI   = $0209         ;HIGH BYTE OF YY COORDINATE
```

```
YYLO   = $0208      ;LOW BYTE OF YY COORDINATE

SDOT   = $0336      ;SUB TO DRAW A SINGLE DOT AT XX, YY

OUTCH  = $0309      ;DISPLAY CHARACTER OR CONTROL IN
                    ; ACCUMULATOR
GETKEY = $0306      ;WAIT UNTIL A KEY IS PRESSED
OFFTCR = $037E      ;TURN OFF THE CURSOR IF IT IS ON
CLRDSP = $0312      ;TO CLEAR ENTIRE DISPLAY

BELVOL = $0228      ;MEMORY LOCATION FOR BELL VOLUME
BELPER = $0227      ;MEMORY LOCATION FOR BELL PITCH
BELCY  = $0228      ;MEMORY LOCATION FOR BELL DURATION
BEEP   = $038D      ;ENTRY POINT TO PRESENT A TONE

        *=$1000

TABLES LDA #00
       STA RND
       LDA #$55
       STA RND+1    ;RANDOM ORDER TABLE STARTS AT $5500
LDA #$F3
STA ITEMS
LDA #$3F
STA ITEMS+1         ;START LOCATION OF ITEMS MINUS 20
                    ; ($4000-$0C=$3FF3)
LDA #$00
STA RSUB1
STA RSUB2
LDA #$60
STA RSUB1+1         ;DEFINE START OF SUBJECT 2 DATA AS
                    ; $6000
SDA #$00
STA SAVE
LDA #$89
STA SAVE+1          ;DEFINE VECTOR FOR SVC 13 (SAVE DATA)
UV1A1  LDA #$80
STA UDDRB1          ;PORT B USER VIA 1: 0-6 = INPUT,
                    ; 7 = OUTPUT
LDA #$00
STA UDDRA1          ;PORT A USER VIA 1: ALL INPUT FOR RND
                    ; NUM GEN.
LDA #$7F
STA U1IER           ;DISABLE USER VIA 1 INTERRUPTS
LDA #$03
STA TIMER1H
LDA #$10
STA TIMER1L         ;LEAD TIMER 1 WITH $03E8 (1000 DECIMAL)
                    ;TIMER 1 IS IN USER VIA 1
LDA #$43
STA U1ACR           ;ACR USER VIA 1 (TIMER 1 = CONTINUOUS
                    ; INTER.) AND LATCH PORT A AND PORT B
```

```
SYS2 LDA #$03
STA SYS2BD              ;DDRB OF SYS VIA 2: BITS 0 AND 1 =
                        ; OUTPUT FOR THE VIDEO OURPUT TO
                        ; SUBJECT MONITORS
LDA #$03
STA SYS2B               ;SET BITS 0 AND 1 OF SYS VIA 2 PORT B
                        ; TO ENABLE BOTH SUBJECT MONITORS
LDA #$04
STA PCR2                ;CA2 SYS VIA2: +EDGE INTERRUPT-READ
                        ;BFF1 CLEARS
LDA #$ 00
STA NFILE               ;ZERO COUNT FOR FILE NAMES
LDA #$40
STA BEL VOL             ;SET BELL VOLUME
LDA #$03
STA BELPER              ;SET BELL PITCH
LDA #$1F
STA BELCY               ;SET DURATION OF BELL
ENTSS LDA #$0C
JSR OUTCH               ;CLEAR THE SCREEN, HOME THE CURSOR
LDA #$80
STA SVCENB              ;ENABLE SVCS
BRK
JSR GET KEY             ;GET THE EXPERIMENTER'S INPUT
CMP #$31
BEQ STRS
CMP #$32
BEQ STRS
JMP ENTSS

STRS AND #$0F
STA NUMSUB              ;STORE IT

SJR CLRDSP

BRK

JMP FILE

INSTR LDA #$0C
 JSR OUTCH              ;CLEAR THE SCREEN
BRK
THE TRIALS',0

LDA #$0
STA SVCENB              ;DISABLE SVCS
JSR GETKEY              ;WAIT FOR A KEY TO BE PRESSED
JSR CLRDSP              ;CLEAR THE DISPLAY
GO LDY #$00             ;CLEAR INDEX
LDA #$00
STA XXHI
STA YYHI                ;PUT ZERO IN HIGH BYTE OF XX
```

```
                            ; AND YY
LDA #$80
STA GMODE                   ;GMODE=DRAW
JSR CALADD                  ;SUBROUTINE TO CALCULATE THE
                            ; TARGET ADDRESS
FIXP JSR VRETR              ;SET UP FOR VERTICAL RETRACE COUNT
WAIT LDA COUNT
CMP #$02                    ;HAS A VERTICAL RETRACE OCCURRED?
BNE WAIT                    ;IF NOT, LOOP BACK
LDA #$80
STA GMODE                   ;SET GMODE FOR DRAW
LDA #143                    ;LOAD DECIMAL 140 AND MOVE IT INTO
                            ; YY LOW
STA YYLO
LDA #231                    ;LOAD DECIMAL 210 AND MOVE IT
                            ; INTO XX LOW
STA XXLO
JSR SDOT                    ;DRAW A DOT AT X=229, Y=140
LDA U1PB                    ;CLEAR THE DATA INPUT PORT
GOLOOP LDA #0               ;ZERO THE VERTICAL RETRACE COUNT
STA COUNT
ONESE LDA COUNT
CMP #10                     ;HAS ONE SCOND ELAPSED?
BNE ONESE                   ;IF NOT, LOOP BACK AND WAIT
GONOW LDA #$00
STA COUNT
SDA #$3E                    ;MAKE THE FIXDURATION=$3E
                            ; COUNTS (992 MSEC)
STA FIXDUR
WAIT1 LDA COUNT             ;LOAD VERTICAL RETRACE COUNT
CMP #FIXDUR                 ;HAS DURATION ELAPSED?
BNE WAIT1                   ;IF NOT, LOOP BACK
LDA #$20                    ;LEAD BEEP VOLUME
LDX #$70                    ;LOAD BEP DURATION IN COMPLETE
                            ; WAVEFORM CLYCLES
LDY #$05                    ;LEAD WAVEFORM PERIOD (UNITS
                            ; OF 200 MSEC)
JSR BEEP                    ;GO PRESENT THE BEEP
LDA #$00                    ;ZERO COUNT
STA COUNT
SDY #$00                    ;CLEAR NUMBER OF LETTERS PRINTED
                            ; COUNT
TRTYPE LDA (PADD),Y         ;GET ITEM NUMBER
INY
STA (RSUB1),Y               ;STORE ITEM TYPE IN SUBJECT
                            ; RESPONSE DATA
STA (RSUB2),Y
CMP #97                     ;IS IT A NON WORD?
BGE NWD                     ;IF YES, BRANCH TO NON WORD
LDA #02                     ;ITEM IS A WORD
STA TYPES1                  ;STORE IT FOR SUBJECT 1
JMP NWI
```

```
NWD LDA #3          ;ITEM IS A NONWORD
STA TYPES1
NWI TA TYPES2
ROL TYPES2
ROL TYPES2
LDA TYPES2
AND #$0C
SSTA TYPES2
INY
LDA #0
STA TCNT            ;RESET THE NUMBER OF LETTERS IN
                    ; THE TARGET
                    ;COUNT
LDY #1
NUML LDA (PADD),Y   ;GET A TARGET ASCII CODE
CMP #$20            ;IS IT A SPACE?
BEQ SUBR            ;IF SO, GET OUT
INY
INY
CPY#13              ;GOT 13 SPACES/LETTERS?
                    ; GONNA LOSE ONE LATER
BEQ SUBR            ;IF SO, GET OUT
INC TCNT
STRNUM CPY #15
BGE SUBT
JMP NUML            ;LOOK AGAIN
SUBT DEY
SUBR DEY
STY NLET
SEC
LDA #40             ;LEAD THE CENTER COLUMN #
SBC,TCNT            ;SUBTRACT THE NUMBER OF TARGET
                    ; LETTER / 2
STA CENTER          ;STORE AS THE START COLUMN #
STA $0200           ;STORE IT AS THE CURSOR COLUMN
                    ; LOCATION
LDA #NTAR           ;LOAD NUMBER OF ITEMS OF THE TARGET
STA NUMTAR
LDA #$00
STAR NUMLET         ;STORE IT IN NUMBER OF LETTERS
                    ; WRITTEN COUNT
LDA #12
STA $0201           ;DEFINE CURSOR LOCATION
WAIT2 LDA COUNT
CMP #$1D            ;HAVE 29 RETRACES OCCURRED
                    ; (464 MSEC)?
BNE WAIT2           ;IF NOT, LOOP BACK
                    ;  IF YES, BLANK SCREEN AND WRITE
                    ; TARGET
JSR BLANK
LDY #1
TARGET LDA (PADD),Y;GET A LETTER
```

```
JSR OUTCH              ;WRITE LETTER ON THE SCREEN.
INY                    ;INCREMENT THE LETTER COUNT
INC NUMLET
LDA NUMLET             ;HAVE ALL LETTERS BEEN WRITTEN?
CMP NLET
BNE TARGET             ;IF NOT, WRITE ANOTHER
DEC NUMTAR             ;IF YES, DECREMENT NUMBER OF TARGETS
                         TO BE WRITTEN COUNT
LDA NUMAR              ;LOAD NUMBER OF TARGETS TO BE
                       ; WRITTEN COUNT
CMP #$00               ;HAVE ALL ITEMS OF TARGET BEEN
                       ; WRITTEN?
DEQ WAIT3              ;IF YES, GO WAIT FOR INTERVAL TO
                       ; ELAPSE
LDA #$00
STA NUMLET             ;ZERO NUMBE OF LETTERS PRINTED COUNT
LDA CENTER
STA $0200              ;RESET COLUMN NUMBER
INC $0201              ;ADD 1 TO LINE NUMBER
JMP TARGET             ;IF NO, GO WRITE ANOTHER
WAIT3 LDA COUNT
CMP #FTDEL             ;HAS TONE-TARGET DELAY ELAPSED?
BNE WAIT3              ;IF NOT, LOOP BACK
JSR UBLANK             ;IF YES, UNBLANK THE SCREEN AND
                         SHOW TARGET
LD #$7F
STA IER2               ;TURN OFF SYS VIA 2 INTERRUPTS
LDA #INTR
STA $02FE
LDA #INTR1
STA $02FF              ;DEFINE ADDRESS OF INTERRUPT
                       ; SUBROUTINE TO BE $5020 FOR
                       ; RESPONSES
LDA U1PB               ;CLEAR IFR FOR CB1 OF USER VIA 1
LDA TIMER1L            ;CLEAR INTERRUPT FLAG OF TIMER1
LDA #$C0
STA U1IER              ;ENABLE TIMER 1 INTERRUPT ON USER
                       ; VIA 1
LDA #$00
STA TIMEL
STA TIMEH              ;ZERO TIME COUNTS
RWAIT LDA U1PB         ;LOAD PORT B OF USER VIA 1 TO
                       ; CHECK FOR RESPONSE
STA TEMPR
AND #$0A
BEQ TOOLNG             ;IF NOT, CHECK TIME FOR MAXIMUM
                       ; WAIT
JMP RESP               ;IF SET, CHECK WHICH SUBJECT
                       ; RESPONDED
TOOLNG LDA TIMEH
CMP #$28               ;HAVE 40 (DECIMAL) 100 MSEC INTERVALS
                       ; ELAPSED?
```

```
BNE RWAIT            ;IF NOT LOOP BACK
JMP EXIT             ;IF YES, LEAVE ACCURACY AND TIME
                     ; AS ZERO AND EXIT
RESP LDY #$02        ;MAKE Y INDEX=2 FOR RESPONSE ACCURACY
                     ; STORAGE
LDA #$0C             ;DID SUBJECT 2 RESPOND?
AND TEMPR
BNE HOWMNY           ;IF YES, GO CHECK TO SEE THAT THERE
                     ; ARE 2 SUBJS.
SUB1 LDA TEMPR       ;LEAD RESPONSE
AND ##03             ;CHECK FOR ONLY SUBJECT 1 RESPONSE
CMP TYPES1           ;DOES RESPONSE=TRIAL TYPE?
BNE ERR1             ;IF NOT, TO TO ERROR
LDA #01              ;IF YES, ...
STA (RSUB1),Y        ;STORE 1 AS THE ACCURACY
JMP TIMES1           ;GO RECORD TIME
ERR1 LDA #$0F        ;ERROR--RECORD $0F AS THE ACCURACY
STA (RSUB1),Y
TIMES1 INY
LDA TIMEL            ;LOAD # MSEC
STA (RSUB1),Y        ;STORE IT
INY
LDA TIMEH            ;LEAD # 100 MSEC COUNTS
STA (RSUJB1),Y       ;STORE IT
LDA NUMSUB           ;LEAD NUMBER OF SUBJECTS
CMP #$01             ;IS THERE ONLY 1 SUBJECT?
BEQ EXIT             ;IF YES, STOP TRIAL
LDY #$02             ;MAKE Y INDEX=$02
LDA (RSUB2),Y        ;LOAD SUBJECT 2 ACCURACY-HAS
                     ;SUBJECT 2 RESPONDED?
BEQ RWAIT            ;IF NOT, LOOP BACK
JMP EXIT             ;IF YES, EXIT
HOWMNY LDA NUMSUB
CMP #$02             ;ARE THERE 2 SUBJECTS?
BEQ SUB2             ;IF YES, IT WAS A REAL SUBJECT 2 RESP.
                     ; SO SCORE
JMP RWAIT            ;IF NOT, IT WASN'T--GO WAIT FOR A
                     ; RESPONSE
SUB2 LDY #$02
LDA TEMPR            ;LOAD RESPONSE
AND #$0C             ;CHECK ONLY SUBJECT 2 RESPONSE
CMP TYPES2           ;IS IT = TO TRIAL TYPE?
BNE ERR2             ;IF NOT, GO RECORD ERROR
LDA #$01             ;IF YES, STORE $01 AS THE ACCURACY
STA (RSUB2),Y
JMP TIMES2           ;GO STORE TIME
ERR2 LDA #$0F
STA (RSUB2), Y       ;ERROR--RECORD $0F AS THE ACCURACY
TIMES2 INY
LDA TIMEL            ;LOAD # MSEC COUNTS
STA (RSUB2),Y        ;STORE IT
INY
```

```
LDA TIMEH         ;LEAD # 100 MSEC COUNTS
STA (RSUB2),Y     ;STORE IT
LDY #$02          ;MAKE Y INDEX - $02
LDA (RSUB1),Y     ;SUBJECT 2 ACCURACY-HAS SUBJECT 2
                  ; RESPONDED?
BEQ RWAIT         ;IF NOT, LOOP BACK
~~JMP EXIT~~          ;IF YES, EXIT
EXIT LDA #$7F
STA U1IER         ;DISABLE USER VIA 1 INTERRUPTS
SDA #$94
STA $02FE
LDA $#E8
STA $02FF         ;RESTORE CODOS IRQ
CLC
LDA R[illegible]B1
ADC #$05
STA RSUB1
LDA RSUB1+1
ADC #$00
STA RSUB1+1       ;UPDATE RESPONSE ADDRESS FOR SUBJECT 1
CLC
LDA RSUB2
ADC #$05
STA RSUB2
LDA RSUB2+1
ADC #$00
STA RSUB2+1       ;UPDATE RESPONSE ADDRESS FOR SUBJECT 2
CHKEND LDY #$01
LDA (RND),Y       ;LOAD MSB OF NEXT RANDOM NUMBER
CMP #$FF          ;IS IT $FF?
BEQ QUIT          ;IF YES, QUIT
JSR CLDRSP        ;CLEAR THE SCREEN
JMP GO            ;IF NOT, PREPARE FOR NEXT TRIAL
QUIT LDA #$94     ;IF YES, RESTORE SETUP AND QUIT
STA $02FE
LDA #$E8
STA $02FF         ;RESTORE CODOS IRQ JUMP
JSR CLRDSP        ;CLEAR THE DISPLAY
LDA #$80
STA SVCENB        ;ENABLE SVCS
BRK
THANK YOU!'
LDA #$00
STA U5
LDA #$89
STA U5+1          ;$8900 IS THE START LOCATION OF THE
                  ; CODOS COMMAND TO SAVE SUBJECT 1 DATA
BRK
LDA NUMSUB
CMP #$01          ;WAS THERE ONLY 1 SUBJECT
BEQ RCODOS        ;IF SO, DON'T SAVE SUB 2 DATA,
                  ; RETURE TO CODOS
```

```
LDA #$1A
STA U5             ;SET U5 TO $891A TO SAVE SUBJECT
                   ; 2 DATA
BRK
RCODOS LDA #$00
STA SVCENB         ;DISABLE SVCS
JMP $E603          ;RETURE TO CODOS; PROGRAM IS DONE

                   ;*************************
                   ;THESE ARE THE SUBROUTINES
                   ;*************************
CALADD LDY #$00
LDA (RND),Y        ;LEAD LSB ITEM NUMBER FOR TRIAL
STA ITNUM          ;STORE FOR MULTIPLY TO CALCULATE
                   ; ITEM ADDRESS
STA (RSUB1),Y
STA (RSUB2),Y      ;STORE LSB ITEM NUMBER IN SUBJECT
                   ; DATA
CLC
LDA RND
ADC #$01
STA RND            ;INCREMENT RANDOM NUMBER TABLE ADDRESS
                   ; FOR NEXT TRIAL
LDA #$80
STA SVCENB         ;ENABLE SVCS
MULTX BRK
                   ; 12 FOR TARGET)
ADDX .BYTE $91     ;ULDA 1 (LOAD U1 ABSOLUTE...)

LDA #$00
STA SVCENB         ;DISABLE SVCS
RTS
VRETR LDA #INTV
STA $02FE          ;DEFINE ADDRESS OF INTERRUPT SERVICE
LDA #INTV1         ; TO BE AT $3000
STA $02FF
LDA #$00
STA COUNT          ;ZERO VERTICAL RETRACE COUNT
LDA #$81           ;ENABLE CA2 INTERRUPT OF SYS VIA 2
STA IER2           ; (VERTICAL RETRACE SIGNAL)
RTS
BLANK LDA SYS1B
AND #$DF
STA SYS1B          ;BLANKS THE SCREEN
RTS
UBLANK LDA SYS1B
ORA #$20
STA SYS1B          ;UNBLANKS THE SCREEN
RTS

*=$3000            ;THIS IS THE VERTICAL RETACE INTERRUPT
                   ; SERVICE ROUTINE
```

```
INTERV PHA
CLC
INC COUNT
LDA SYS2A                ;CLEAR IFRO
PLA
RTI

*=$3000                  ;THIS IS THE TIMER 1 INTERRUPT
                         ; SERVICE ROUTINE
INTERR PHA
LDA #$E8
STA TIMER1L
LDA #$03
STA TIMER1H              ;RESTART TIMER 1 AND CLEAR INTERR. FLAG
INC TIMEL
LDA TIMEL
CMP #$64                 ;HAVE 100 MSEC ELAPSED?
BNE OUTINT               ;IF NOT, RETURN FROM INTERRUPT
CLC                      ;IF YES, ADD 1 TO # 100 MSEC COUNT
LDA TIMEH
ADC #$01
STA TIMEH
LDA #$00                 ;AND ZERO THE # MSEC COUNT
STA TIMEL

OUTINT PLA
RTI
```

APPENDIX J

Literature Review

LITERATURE REVIEW

Models of Lexical Access:

Empirically some words are recognized more quickly and accurately than others. The normative frequency with which a word appears in written language, and the context in which it is presented alter recognition times (Becker, 1980; Becker & Killion, 1977; Conrad, 1974; O'Conner & Forster, 1981). These two effects have been viewed as most fundamental to word recognition. However, early theory concerning the unitization of these effects proved unwieldy. So, both theoretical and empirical accounts began to dissociate frequency and context effects, with a growing consensus concerning the importance of frequency on word recognition (Whalley, 1978).

As well, early word recognition theory was strongly dependent on perceptual theory. thus the physical aspects of letter recognition and its ensuing word recognition were emphasized in these early accounts. More recent studies have begun to dissociate the previous almost obligatory status of the letter to word transition (e.g., Ogden, 1984) and thus to examine the nature of this transition from letter recognition to lexical access (e.g., Mozer, 1983).

This literature review is directed towards providing a rational for the study of compound words in the search for supra-letter subunits in word recognition processes. Equally as important, this review concentrates on the role of frequency in lexical access theories, with the view that familiarity is the most consistently reliable predictor of word recognition latencies (Gernsbacher, 1984).

Morton (1969, 1970) proposed one of the first models of word recognition. In his 'logogen' model, recognition is accomplished by a system of devices, called logogens. Each logogen accepts information from sensory analyzers and from context. Each logogen is defined by both the information (sematic, visual and acoustic) that it can accept, and also by the response (i.e., word) that it makes available. Finally, suprathreshold activation of the logogen actually signals the presence of a particular word.

Morton depicts the logogen as a passive counting device. Each time a sensory feature is abstracted (by the feature analysis system), sent (to the logogen system) and matched (to one of the features of that logogen), the logogen responds by incrementing an internal count for that specific word. When this count of matching features rises above a certain threshold, the recognition response is made available.

At this point, the word is recognized. At the same time, all other logogens are prevented from exceeding their thresholds. According to Morton, frequency effects on word recognition are accounted for by differences in these thresholds. The logogens of high-frequency words are said to have chronically lower thresholds and thus require fewer inputs to exceed threshold. Conversely, low-frequency words with higher thresholds require more extensive processing (i.e., feature analysis) before their logogen is activated above threshold.

This process of feature analysis is assumed to take time. Therefore, the necessity for more feature matches with low frequency words underlies the greater time required for their recognition. In Morton's model, threshold changes also underlie the response time advantage of words presented in a relevant context. Context temporarily lowers the thresholds of related words, thus reducing the number of feature matches (and therefore, time) necessary for recognition of context relevant words.

Morton's idea was that both frequency and priming worked at the same stage of stimulus recognition. Becker and Killion (1977) tested this hypothesis using a Sternberg-type paradigm. In a series of four experiments, they found that semantic context interacted with stimulus intensity in word recognition. As well, they found that stimulus intensity was additive with word frequency effects. Using Donders (1968) subtraction method (Gottsdanker & Shragg, 1985), Becker and Killion conclude that context and frequency effects cannot operate at the same stage of word recognition. Interestingly, these data show frequency effects of greater than 100 ms but context effects of between 30 and 70 ms. So even here, frequency begins to look like the more distinctive factor governing reaction times in word recognition processes.

In order to deal with this 1977 data, Becker (1976, 1980) proposed a 'verification' model of word recognition. Becker's model retains some aspects of Morton's logogen model but provides for a very different theoretical account of the effect of frequency. Similar to the logogen model, the presentation of a stimulus and its depiction in sensory memory initiates feature extractions. This processing provides feature information to an array of word detectors.

Much like logogens, the detectors accumulate sensory information. However, when a detector exceeds its criterion, the stimulus is not automatically recognized. Rather, it is assumed that feature extraction identifies only more 'primitive' components of the stimulus, i.e., line segments and arcs. However, feature extraction cannot identify and/or transmit the relations among primitives, although Becker considers this information essential in word recognition. The result of successful feature extraction is the delineation of a set of possible words or, candidates each of which is consistent with the primitive information.

Another process, verification, now operates on this set of candidates to specifically identify the stimulus word. It is only now during verification, that the additional information stored with the word (i.e., the relations between the primitives) is used to construct a complete visual representation of the word. Each constructed representation is then serially compared with stimulus information in sensory memory either successfully or unsuccessfully. And it is during this stage that Becker considers frequency important. He considers the candidate set to be ordered and the verification process to proceed such that the higher frequency candidate words are first to be verified while low frequency items are last.

Each verification cycle is assumed to take place in real time. Lower frequency words are assumed to require more verification cycles to get to the bottom of the candidate set for a successful match. This provides the source of slower recognition of these words.

Thus, the effects of frequency on word recognition are quite different for Morton and Becker. Although both theories propose an initial feature extractions stage, Morton conceptualizes frequency effects as threshold phenomena and thus 'early' in the recognition process. Becker, on the other hand, conceives of frequency as acting to determine item order in the verification of a candidate set of words. This is a distinctly 'later' stage in Becker's word recognition model.

Both theories provide a framework that accounts for much of the experimental data concerning frequency effects in word recognition. However, some basic ideas are not addresssed by Morton and Becker. For example, if supra-letter features contribute to lexical access, then the construction of non-word stinuli and the responses to those stimuli become important issues. However, either theory directly addresss the issue of the 'No' response, i.e., what happens when the stimulus is a non word or pseudo-word? In fact, Becker often omits nonword data from his reports.

In the same vein, these theories do not directly question the effects of information about letter combinations in real word stimuli. Yet, letter combinations do vary in the frequency with which they appear in written language. And this information has been said to affect lexical access (Rumelhart & Siple, 1974). Yet, neither Morton nor Becker specifically postulate the existence of intermediary steps or units between letter recognition and word recognition.

An extension of Becker's model by Paap et al (1982), however, does incorporate this type of letter information in the form of an internal alphabetum. These authors view feature extraction and encoding as a process that involves matching features to various types of units. Essentially, their model proposes two types of units: whole words stored in a lexicon and letters stored in an alphabetum.

In the alphabetum, individual letters are represented by a feature list. The relative level of activation for each letter unit is detemined by the number of matching features that have been detected. Thus, word units are activated to the extent that constituent letters are activated in the alphabetum.

Paap believes that supra-letter features contribute to the activation level of word units (p. 575). However, he does not elaborate on this statement. In fact, his research all involves words composed of four-letter upper case strings. In this way, he certainly avoids many of the more distinctive supra-letter features, such as prefixes, suffixes, or even words-within-a-word, that are sometimes present in longer lexical units.

The interactive-activation model of lexical access tries to directly address exactly the issue of supra-letter subunits. Thus, McClelland and Remelhart (1981), Rumelhart and McClelland (1982) are specifically concerned with the interactions of letters in word perception. In this model, information processing is grouped into levels. Although their theory provides for a large number of levels, Rumelhardt and McClelland limit consideration to three levels: the feature level, the letter level, and the word level. Each level consists of a set of units or nodes: one node for each possible element at that level.

Rumelhart and McClelland provide a fairly elaborate mechanism for the interaction of nodes within a single level as well as between adjacent levels.

They assume that each node has connections to a number of other nodes. The nodes to which a node connects are called its neighbours. In the absence of any inputs from its neighbours, all nodes are assumed to be in a resting state. This resting activation level may differ from node to node and is determined by the total number of activations of that node. Thus, the nodes for high frequency words have resting levels higher than those for low frequency words.

When the neighbors of a node are activated, they affect the activation of that node either positively or negatively depending upon their relation to the node.

However, this model of word perception is also assumed to be spatially parallel; that is, capable of processing several visual units at once. As well, these authors propose that visual processing occurs at several levels more or less simultaneously.

Stimulus presentation initiates feature extraction, and information is transmitted to the letter nodes. Appropriate letter nodes are activated above their resting levels; others are pushed below their resting levels by negative inputs. In turn, letter nodes send activation to consistent word nodes, and inhibit inconsistent word nodes. And, as the word nodes become activated, they communicate with other word nodes. In addition, the word nodes feedback to the letter nodes enhancing particularly consistent features and inhibiting other features.

This concept of "top-down" processing is used to explain Reicher's (1969) data. Reicher presented target letters in words, nonwords and alone. Following a pattern mask, subjects were tested using a two-alternative forced choice. Performance was more accurate for letters in words than either control condition. Thus, perception of a single letter can be facilitated by presenting it in the contest of a word. McClelland and Rumelhart assume higher level inputs drive the letters in words to higher activation levels.

Even here, frequency effects are felt. A significant relationship exists between single-letter frequency and accuracy of report (Mason, 1975; McLelland, 1976; McLelland & Johnston, 1977)

The interactive-activation model fails to address or make predictions about word perception when there is more than one meaningful and physically distinct lexical unit within the word boundaries (for example, compound words). Rumelhardt and McClelland address the letter-within-a-word issue, but not the word-within-a-word issue.

Empirically, whole word exposure is not the only type of knowledge that can enhance perceptual processes. A number of studies have shown that nonwords are reported more accurately if they are orthographically regular (Baron & Thurston, 1973), or, if they are made up of various types of subunits, such as "spelling pattern units" (Aderman & Smith, 1971) or "vocalic center groups" (Spoehr & Smith, 1975). Despite some contradictory reports (Manelis, 1974; Chambers & Forster, 1975), there also appear to be bigram frequency effects in this literature (Rice & Robinson, 1975). Even so, McClelland and Johnston (1977) provide evidence against letter-cluster units in lexical encoding. Therefore, McClelland and Rumelhart have real difficulty postulating an intermediate level of detector between letters and whole words, as it would directly contradict the McClelland and Johnston data.

Therefore, in examining the compund word, it may be more appropriate to consider lexical access theories that define encoding in terms of meaningful 'chunks' within a word. The traditional approach has been to consider these 'chunks' as syllables, usually defined in terms of phonology. That is, syllables have been associated with groups of phonemes usually consisting of a vowel nucleus and both anteceden[illegible]nd following consonants (Framkin & Rodman, 1983, [illegible]47). Spoehr and Smith (1973; 1974; 1975) propose[illegible]nologically mediated model of word recognition based on syllabic parsing rules. In essence, their theory of visual word recognition is based on the way the word sounds.

For these authors, stimulus presentation is followed by feature extraction. This process is very similar to the theories presented previously. The feature extraction process assigns letter identities to each position in the array. However in opposition to previous theories, Spoehr and Smith say that this letter information cannot direct the response process.

Instead, a 'parsing' process now operates on the stored letters, segmenting them into "higher-order" units (i.e., syllables). They call this parsing process, unitization. These syllables are equated with the 'vocalic center group' that Hansen and Rogers's (1973) postulate as the unit for speech production. For Spoehr and Smith, this unitization process involves translation into a phonologic/articulatory code. It is this code that is stored in short-term memory and is available for response production.

At least at the level of whole words, their assumptions receive some support (Meyer, Schvaneveldt, & Ruddy, 1974; O'Hara, 1980). However, even with whole words, phonological encoding fails to provide for all types of lexical access (Hillinger, 1980).

In contrast to Spoehr and Smith's phonologic/auditory encoding theory, Taft (1975) has proposed a theory of lexical encoding based on a written syllable. Taft's (1979) Basic Orthographic Syllabic Structure theory (BOSS) rests on two primary assumptions: morphologically related words are accessed through an identical, shared entry in the lexicon, and words are accessed on the basis of their first syllable. A morphene is defined here as the basic element of meaning. That is, a morphene consists of a phonological form arbitrarily united with a particular meaning that cannot be analyzed into simpler elements (Fromkin & Rodman, 1983, p.114).

Taft argues that lexical access based on a phonologically defined syllable (like the one proposed by Spoehr and Smith) would often result in morphologically related words being accessed through different lexical entries. In contrast, his model preserves morphological relationships by assigning a common root to related words. For example, although FAS is the phonologic entry of FASTER, both FASTER and FAST have FAST as the BOSS allowing both words to be accessed through a common entry.

And BOSS theory does address the recognition of compound words. The first word of the compound is the BOSS while the second word acts a a suffix. That is, the compound word is composed of word-1 and word-2 where word-2 serves as a suffix to word-1. According to BOSS theory, word-1 is the defining unit. It serves as the access root during whole-word recognition. In this way, Taft treats compound words exactly the same way as other (complex) words. In fact, Taft often reports his compound word and complex word data together, treating both types of words as representatives of a single phenomena.

Taft and Forster (1976) provide some compelling evidence for BOSS theory predictions. They predict that a high frequency first word in a compound word will provide faster recognition than a low frequency first word. Using a lexical decision task, they demonstrate that HEADSTAND (high frequency first word) is faster than LOINCLOTH (low frequency) where both words are matched in overall frequency.

The study has some serious limitations in methodology. First, both word and 'nonword' items are composed of real English words. Examples are: a high frequency word, HEADSTAND; a low frequency word, LOINCLOTH; a high frequency nonword, STONEFOIL; a low frequency nonword, STALEGRIP. Yet, the study used a lexical decision task, which, almost by definition, demands that the foils be distinctively different than the target items.

As well, "word" items were repeated in the experiment. Both HEADACHE and HEADSTAND were used as 'word' items but no analysis for the repetition is provided. Interestingly, these authors get a reverse frequency effect for their 'nonword' foils. But they dismiss this fact that the low frequency 'nonwords' are faster than those of high frequency.

However, they themselves (Forster and Chambers, 1973) say that a nonword is equivalent to a very rare word. In fact, in this experiment, they even consider letter strings such as HENCH as low frequency words, thus using this nonword equivalence principle. On the one hand, Taft considers compound words composed of real English constituents (e.g., STONEFOIL) as 'nonwords'. On the other hand, he considers item strings that do not appear in the dictionary (e.g. HENCH) to be real English words.

If we apply his word principles consistently, we might view these (Taft & Forster, 1976) data as indicating an interaction between overall word frequency and the frequency of constituent (subunit) words. That is, high frequency compound words show a frequency effect for the first item while low frequency compound words (Taft and Forster's, 1976, 'nonwords') show a reverse frequency effect for the first subunit.

Taft (1979a) used these Taft and Forster (1976) data as part of the rationale behind investigating frequency effects in both prefixed and suffixed words. [illegible] this study, as in Taft and Forster (1975), all stimuli are complex (polysyllabic) words, or portions thereof. In combining all of these results theoretically, Taft lumps his compound and complex word data together. He concludes that frequency effects are determined by the total frequency of the root word. Total root frequency refers to the sum of the frequencies of all the real words that the root word could access (according to BOSS theory).

Contrary to the Taft and Forster (1976) data, the surface frequency of the word continued to be the deciding factor in lexical decision times in the 1979(a) data. Taft demonstrates an effect for subunit frequency in his 1976 data using compound words, but fails to replicate it using affixed words in 1979(a). In combining his complex and compound word results, he may well obscure real effects.

Carpenter (1984) has a very different approach to compound words. Carpenter views compound words as being uniquely composed, usually of two nouns: noun-1 and noun-2. Here noun-2 is the identifier for the word (defines the whole word) while noun-1 modifies noun-2. Thus, in the example, FOOTBALL, Carpenter would say that noun-2 (BALL) defines the whole word, while noun-1 (FOOT) tells something specific about the word BALL.

To summarize these two word-within-a-word theories, then, Carpenter sees the compound word as composed of an 'adjective-noun' combination. Taft, on the other hand, views the compound word as composed of a 'noun-suffix' combination.

At least in the case of whole words, frequency still remains the most distinctive variable determining lexical access (Gordon, 1983; Grossberg & Stone, 1986). However, neither Taft nor Carpenter have systematically examined the effect of internal word frequency on compound whole word recognition. In fact, both these authors seem to prefer word segmentation and internal rearrangement as experimental tools.

Lima and Pollatsek (1983) capture the spirit of this style of scientific endeaver. They present letter strings in four different forms in a lexical decision task. In the whole condition, the letter string is presented in its normal, undivided form, and in the three divided conditions, the letter string is split into two segments by a space. Thus segments were divided on the basis of BOSS rules, phononlogic (i.e., Spoehr and Smith) rules, or one letter was added to the BOSS segment. No rationale is offered for this segment. Their first experiment examines these segmented words in a lexical decision task. Additional experiments investigate priming effects using either the segments (as above) or prefixes and suffixes as the priming materials to the whole word.

Lima and Pollatsek analyze their data separately for compound words. They find that the best prime for a compound word is a constituent word, which is consistent with Taft and Forster (1979b). However, the rest of their results are an array of conflicting data. Given the difficulty of the experimental paradigm, it is not unexpected that they both support and contradict their own data in this series of three experiments.

The goal of the research reported and proposed here is, therefore, to systematically examine the effects of global and unit word frequency in compound word recognition. Experiment 1 compares compound words to complex words, thus directly testing Taft's implication that compound words are not different than other words. Experiment 2 examines reaction times in a lexical decision task with high and low frequency compound words selected for high and low frequency internal unit words, specifically attempting to define internal frequency effects for compound words.

Experiment 3 is proposed to examine repetition effects in compound words. Repetition has been likened to frequency in its effects on word recognition (Jacoby, 1983). Because of counter-balancing problems in Experiment 2 (i.e., it is almost impossible to find a high frequency compound word with low frequency units), I chose repetition as a alternate method of manipulating prior exposure to stimulus materials.