LETTER IDENTITY AND PHONEMIC COMPARISON

LETTER IDENTITY AND PHONEMIC PROCESSING IN WORD COMPARISON: THEIR RELATIVE ORDERING.

by

IAN MUNRO THURSTON, M.A.

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AUTHOR: Ian Munro Thurston, B.Sc. (McGill University), M.A. (McMaster University)

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The view of some is that people process printed words in a highly flexible fashion, attending to now this characteristic of a word, now that, as the task demands it. This thesis, after discussing some models of the types of information in words and the relationships among these types of information and their processing, reports experiments showing three different effects which demonstrate that there are restrictions on the ways in which information about the appearance of letters and their identity is processed relative to information about the phonology or pronounciation of the words. These limitations are explained in terms of a model in which phonemic information becomes available completely at a later time than visual features or the identity of letters in a word. It is argued that the most likely form of this model is one in which visual features and letter-identity become available as a result of the operations of an early processing stage or stages, while phonemic information becomes available as a result of the operation of a subsequent stage, the input of which is the output of the first.

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I dedicate this thesis to my grandfather, William Tait, who lived by his own lights, and to his wife, who lived by others'.

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This thesis adopts the analytic view of visual word processing, which is that there are many potential types of information conveyed by a written word, and that word processing consists of analyzing words for these different types of information. However, it does not take the problem-solving view of word processing, which can lead to the assumption that subjects concentrate on the types of information necessary to the task at hand, while ignoring other types of information. The high flexibility this ascribes to word processing is felt by some (Baron, 1973) to be atypical of the procedures employed most of the time by experienced readers.

Instead, the thesis assumes that, since word processing is for most people a highly practiced skill, there may be preferred strategies for analyzing quickly available, reliable information, and some definite order in which these types of information are analyzed. These strategies are not evident when the limits of perception and the ability to snatch information from a brief visual presentation are studied, but they become evident using some of the methods described in this introduction. As such, they put a limit on the flexibility with which people process clearly legible words when response time is at a premium.

In this introductory section, the views of word processing as problem-solving or as a skill are described briefly. Than, it is specified that the thesis will concentrate on two particular types of information, namely letter-identities (what the letters in a word are, regardless of their physical idiosyncracies), and phonemic representations (how the words would sound if spoken). The nature of the "feature-analytic" model of word recognition and how it accommodates these and other types of information are then outlined. Several views of how processing for the different types of information is interrelated are specifically described.

Three methods for exploring these relationships are then set out. The three chapters following the introduction each contain experiments using one of the methods. Experiments I to III, using Cohen's method, and Experiments X to XIII, using a transfer method, together show that letter-identity information becomes completely available for a response during phonemic processing, but that the converse is apparently not true. Experiments IV to IX show that phonemic information can usually be ignored during letter-identity processing, but not conversely.

In the final chapter, it is concluded that subjects are relatively inflexible in their ability to ignore phonemic information and not ignore letter-identity information in these tasks. This conclusion is unlike what we would predict based on a view of word-processing as mostly problem-solving, but is quite consistent with the view of reading and word-processing as highly practiced skills. A model of word-processing in the tasks described in this thesis must be so constructed as to predict that letter-identity information becomes completely available before phonemic information. It is concluded that the most parsimonious model is that letter-identity processing must occur before phonemic processing is the output from letter-identity processing.

Reading as skill rather than problem-solving

Much use has been made of the tachistiscope in the study of word processing, to the point where it seems as indispensable to the reading laboratory as is the scalpel to the physiological psychologist. From Cattell to Sperling, psychologists have examined the amount of information which can be extracted from letter stimuli in brief exposures, influenced by the assumption that somehow such exposures duplicate the inter-saccadic pauses that occur during reading, and thereby capture in miniature an elementary act of reading.[4]

Unfortunately, with the tachistiscope method there is little control over what information the subject uses and (more critically) how long he takes to use it. Clearly, the subject makes use of all available cues, squeezing out every drop of information in an effort to identify stimulus information which is presumably disappearing rapidly. Indeed, the early work of Zeitler (in Huey, 1908) and of Erdmann and Dodge (1898) suggests that the more available redundancy in the stimulus, the more accurately the subject performs - results confirmed by later investigations by Miller, Bruner and Postman (1954). This increase in use of information is not a sudden step-wise jump as we would expect from the presence or absence of one type of information (for example, grammatical information), but is suggestive of a broad strategy whereby the subject draws on as many sources of information as possible. The subject, however, is not limited in his processing entirely by stimulus exposure duration, even under conditions of masking. Thus even if a stimulus display is "masked" by presentation of another, subsequent display, useful stimulus-based information may be present after masking - changes in accuracy due to the interval between stimulus onset and mask onset may be due in large part to changes in the clearness of the visual image formed by that time, and not to the annihilation of that image (Neisser, 1967).

As such, tachistiscopic recognition studies can indicate sorts of information that could possibly be used in word recognition. On the other hand, many experimenters using such methods tacitly accept a view of word recognition as a form of problem solving, with seemingly unlimited time to permit decisions about what information to use and what to ignore. For example, Huey (1908) feels that "reading is now by letters, now by groups of letters or by syllables, now by word-wholes, all in the same sentence sometimes, or even in the same word, as the reader may most quickly attain his purpose." This view would seem to require a level of processing at which decisions are made about what mode of word processing should be used; such decisions, apparently, could occur almost as often as the processes (about which they decide) do. On what information these decisions about mode of processing might be based is not clear. Interestingly, Huey's view of reading is remarkably like that of Gibson (1971), who feels that there are shifts of processing strategy as task demands vary in reading.

This 'problem-solving' view of reading ignores the obvious fact that subjects do not have a large or unlimited time in which to respond to the information from a given area of the printed page - rather their eyes scan different portions of a page in rapid succession, at a relatively uniform rate. Unquestionably readers make use of different kinds of information during reading, but time is at a premium, and it must be on those types of information which are usually available quickly and easily that subjects principally rely.

As a consequence of the demand that certain types of information be available quickly and easily, we would expect two effects on the strategy of word processing in reading. The first effect is that with practice, subjects will come to learn which types of information are usually reliable and easy to acquire, and employ such information in reading as a preferred strategy (though not to the exclusion of other types of information where necessary). That such reliable information exists in abundance in written English is unquestionnable (Neisser, 1967); that it is used by preference is a matter of investigation. The second effect we expect is that with time, this strategy will become established as a well-practiced collection of processes connected in a relatively invariant fashion (Lashley, 1951). Both of these effects seem more likely than that the subject should shift his mode of processing from moment; such a strategy would be as extravagantly time consuming as it would be wasteful of the obvious regularities of the written language (Gibson, 1971).

In essence, experimenters have chiefly asked questions about performance when stimulus exposure duration is brief, and under the control of the experimenter; what is also needed is to examine performance when the stimulus exposure duration and time to respond are under the control of the subject and must be minimized. Such a situation is in some ways more commensurate with the demands on the subject in reading, but more importantly any tendency to rely on all the information potentially available, while encouraging reliance on only necessary and sufficient information processing. Though the conclusions reached in such a situation need not relate directly to reading, it is hard to conceive that processing limitations which result from years of reading practice would not be reflected in performance studied in this way.

As an alternative to the tachistiscopic procedure, I have chosen the discrimination of simultaneously-presented pairs of words as 'same' or 'different', (the two-alternative forced-choice procedure). This method has the advantage of allowing different tasks to be specified for the same stimuli, thereby ensuring that the subject processes at least the information designated by the experimenter. The data of interest can be the accuracy of discrimination, but the method is especially suited to measuring latency of response, and if instructions emphasizing speed and accuracy are given, then it is to be expected that not only does the subject make use of the information designated, but that he responds as soon as sufficient information is available, without continuing to process for additional, confirming information.

At this point, a choice has to be made as to which types of word information will be studied. Posner and his colleagues (Posner and Mitchell, 1967; Eichelmann, 1970) have examined the relationship between physical information and what they call 'name' information using the two-alternative forced-choice method for both simultaneous matching and sequential (memory) matching. However, their procedure did not specify which of the many possible "codes" or " features" were to be used by the subject to decide that two physically different stimuli (e.g. A and a) are nevertheless the same. Therefore, subjects might have been relying on letter-identity information, phonemic information, semantic information, or combinations of these.

Baron (1973) compared the visual discrimination of homophone pairs to discrimination of non-homophone pairs differing in the same letters. The use of homophones (e.g. FOUR - FORE) represents a method of controlling the phonological information a subject could extract from the stimuli (in this example, though the visual characteristics, letter-identities, and meanings of the two words differ, they sound and are articulated identically). The experiments of Posner described above involve stimuli that are matched for all information save physical. And to a certain extent, synonyms represent words which differ for other information, but have identical or nearly identical meaning. Words with several meanings, such as 'dice', can function as stimuli which are identical for all information save semantic; while words like "lead" and "tear" can differ in phonological and semantic information even though they match physically (and hence match for letters too). Table A shows some pairs of stimuli which can be matched

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Insert Table A about here

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for various kinds of information. Notice that there are no examples of word pairs which have identical features but different letters. Because of the difficulty of specifying exactly what is meant by semantic information at the present time, it seemed wisest to leave the relationship between semantic information and other types of information to later investigations. Some will argue that by doing so, one abandons the study of reading processes, and that consequently any such investigations can have no bearing on the theories of reading described above. The reply must be that if reading is the complex act it is touted to be, limitations found in simpler tasks must either influence reading or be overcome in reading. Furthermore, strategies developed for word processing in

TABLE A

Pairs of words which can be compared for different classes of information.

STIMULUS PAIR	FEATURES	LETTERS	PHONEMES	MEANING
BARE BARE	+	+	+	+
BARE bare	-	+	+	+
DICE (noun) DICE (verb)	+	+	+	-
DICE dice	-	+	+	-
LEAD (noun) LEAD (verb)	+	+	-	-
LEAD lead	-	+	-	-
TOMATO (tomayto) TOMATO (tomahto)	+	+	-	+
TOMATO tomato	-	+	-	+
THO THOUGH	-	-	+	+
BARE BEAR	-	-	+	-
RING CIRCLE	-	-	-	+
BARE BORE	-	-	-	-

("+" indicates that a pair of words match with respect to the kind of information at the head of the column in which the sign occurs.)

reading must certainly come into play in other word-processing tasks to varying extents.

I have therefore chosen to concentrate on letter-identity processing and phonemic processing. Early theoretical views of word-processing did not often support the view that letter-identity and phonemic representations played any crucial role in access to meaning during reading. The "template" model to be described subsequently exemplifies this, and were it valid, the relationship of this thesis to the study of reading processes would be rendered dubious. However, the "feature-analytic" model described after has supplanted the template model, and it postulates that considerable analysis of a printed word can occur during word-processing, and by extension in reading. These two models will now be described briefly.

The Template Model of Word Recognition

Some early experimenters such as Zeitler (in Huey, 1908) believed that visual word recognition processes operated so that the word as a whole was analyzed, rather than its constituent parts. Such a belief led to models of word recognition through what has been called canonical forms, prototypes, or, more familiarly to modern theorists, template matching (Neisser, 1967). According to this theory, every new occurance of a word-stimulus is matched against a stock of basic models of the words known to the subject for congruence. The word-model with which the stimulus has maximum congruence is selected as the word presented.

This theory was rejected by the Gestalt theorists and cannot be accepted today for several reasons. It cannot account for the ability of subjects to identify and otherwise process words printed in many orientations and transformations of geometric relationship (Kolers, 1966). Subjects are relatively unaffected by variations in type font, which is hard to explain if a single prototype exists for each word. The stock of prototypes for the experienced reader could be based on 10,000 to 100,000 words - a prohibitively large lexicon to be stored and searched through if there were different models for each type font in which a word could occur. Subjects can and do recognize words they have never seen before; in fact, the word-superiority effect, which is one of the reasons for postulating whole-word recognition, has been shown to operate for neologisms or nonsense words, provided only that they conform to spelling rules of the language (Baron and Thurston, 1973).

The template model of word recognition, finally, is unlikely to be true because a template model cannot even account for the recognition of isolated letters, let alone words. The template model fails to cope with letters just as it fails to cope with words (or nearly any kind of pattern) because it cannot account for the ability to recognize transformed and distorted versions of the letters. Thus a template model is insufficient; this does not mean that whole word information is not sometimes used to aid reading, only that, by itself, such whole word information cannot be sufficient to permit complete and easy access to word identity.

The Feature-Analytic Model of Word Recognition

As an alternative to template matching theories of word recognition, many modern theorists (Gibson, 1971; Neisser, 1967; Selfridge, 1956; Uhr, 1963) have proposed that word-recognition be thought of as a subset of the problem of pattern-recognition. As is indicated elsewhere, this approach, though it has been fruitful, may tend to encourage the conceptualization of reading and word-recognition as an exercise in problem solving, to the exclusion of its equally important nature as a highly-practiced, rapidly-executed skill.

Such concentration on the possible strategies to which subjects can be forced to resort, at the expense of concentrating on the preferred tactics of word processing, can at best lead to a largely one-dimensional view of word recognition and reading.

According to these theorists, word recognition proceeds through the operation of "feature analyzers" or processes which respond to the "features" of a word stimulus. There are certainly many potential "features" or "attributes" of a word; in fact it is hard to pin down the "features" that a model deals with, though there are exceptions (Sperling and Speehlman, 1970).

Gibson (1971) identifies five categories of features corresponding to conceptually possible types of information in words. First, there are 'graphological' features, corresponding to the physical structure of the word. For example, the word as a whole has shape, length and so forth; within the word, individual letters and combinations of letters have many different features, such as presence of line segments, convexity, closure, and a host of others. Then there are orthographic features corresponding to the combinations of letters in the word, and their conformity to the orthographic rules of English. Gibson conceives of these features as belonging to the same class as graphological features.

There are phonological features, even when a word is read, as we observe when reading poetry, for example. There are many semantic features such as class membership (Wickens, 1970). And finally, there are syntactic features, such as part of speech, possible role in a sentence, and "marking" (the presence of a group of letters indicating, for example, tense or pluralization).

In this thesis, we will not be concerned with semantic or syntactic features. We will, however, be concerned with visual features (i.e. with graphological and orthographic features) insofar as they contribute to ascertaining the identity of the letters in words, and with phonological features insofar as they help attain a phonemic representation of a word.

There are good reasons for supposing that graphological information (about such characteristics as type font and spelling patterns) is not only extracted during processing of a word, but persists for some time after this extraction (Posner <u>et al</u>, 1969). Similarly, when recall of visually presented patterns is required after brief (Sperling, 1963) or prolonged visual displays (Conrad, 1964), confusions which are apparently attributable to phonemic (or phonological, or acoustic) confusion occur and may predominate over visual confusions. This suggests a recoding of the visual stimuli into a form like that produced by auditorilly presented stimuli. It might be argued that we do not at present know the <u>forms</u> in which graphological and phonological (phonemic) information are encoded, or indeed if there is any sharp distinction between graphological features and phonological features other than an arbitrary conceptual one.

The actual <u>form</u> of the information which permits graphological comparisons of words (e.g., are they spelled similarly, or written in similar fonts) and phonemic comparisons (are the words similar in sound or pronounciation) is not crucial to the investigations reported in this thesis. Whatever the case, such information must currently play the role of an intervening variable, which is presumed not to change value from experiment to experiment in the studies described hereafter.

Finally, the feature-analytic model of word processing is the most fruitful general conception, in no small part because it easily handles the ability subjects have to rapidly discriminate words on many bases; rather than assume subjects learn new discriminations during experimental tasks, it is far easier to postulate that the information necessary for discrimination becomes available during the course of perception. Gibson makes this assumption explicit by stating that we perceive words as complexes of features; however she quickly adds that words are also entities which have an internal existence, presumably apart from the lists of features with which they are associated. Neisser is more specific, stating that internal representations of words are mediated by, indeed synthesized from features, and that the features are "as meaningless in themselves as the bone chips of the paleontologist". Morton (1970) and Laberge and Samuels (1973) have proposed models which account for word identification in terms of the activation of internal codes or indicators which represent the presence or absence of a given word.

Concatenation of Processes

If the subject does analyze a written word for different classes of information one of the most interesting questions we can ask is how these various types of information are combined in word processing.

It is to this question that this thesis in part addresses itself. Therefore, several methods of determining the order and combinations in which information becomes available to the subject will be described. Some of these methods are inapplicable to the study of word processing for various reasons; others have been selected and will be examined in more detail before the experimental applications which make up the corpus of research for this thesis are described.

First, a brief account of some theoretical views of the order in which information becomes available in word processing should be given. At the outset, it should be made clear that a feature-analytic model of word processing need not require that one type of information be completely analyzed before analysis of another type of information begins. Neisser, for example, conceives that the subject decides on a rate of analysis which optimizes economy and speed within an acceptable range of error.

Neisser has proposed a number of alternative conceptions of how feature-analytic mechanisms could act in concert in word processing. One such conception is that of the <u>operationally parallel system</u>, in which no analyzer depends on the course or outcome of processing by other analyzers; a contrasting alternative is the <u>sequential system</u>, in which analysis occurs in successive, interrelated steps, and the output of earlier analyzers determines which analyzers are to be used later. Other possible alternatives exist and must be considered: The course of processing of one analyzer may be determined in part by the course of processing of another analyzer operating at the same time. And there may be a definite temporal ordering of the operation of analyzers though they operate independently of one another's output (for example, it might not be possible to process for one type of information until processing is complete for another type, even though the two analyzers operate completely independently and are not affected by each other's outcome).

Gibson (1971) asserts that graphological, phonological, and semantic information from words are analyzed (into features) independently and in that sequence; in support of this view she cites the "semantic satiation effect": to whit, with a prolonged exposure to a given word, subjects report that information "drops out" of availability. This occurs in a definite order, with semantic information "dropping out" first, then phonological information, and finally graphological information. Presumably the prolonged exposure results in fatigue, with the deepest, most abstract analysis suffering first, followed by successive 'layers' or 'levels' of analysis. Depending on the demands of his task, the subject attends to or suppresses any particular type of information; Gibson suggests that the filter mechanisms described by Treisman (1969) may be the method by which this is accomplished.

Presumably Gibson means by "independent extraction" that the subject first processes the stimulus for graphological information; then the subject extracts phonological information, then semantic information. But it is not clear whether she means us to believe that phonological information is extracted from the results of graphological processing, and thus is sequentially dependent on graphological processing, or whether she instead means that the subject reanalyzes the stimulus for phonological information when graphological analysis is completed. In the former case, errors or changes in graphological processing would change the input to the phonological processing which followed, producing some changes in the output of phonological processing too; this would be a sequential system in Neisser's sense. In the latter case, the course and output of phonological processing could be truly independent of graphological processing.

On the other hand, Rubenstein et al (1971) propose that phonological information and graphological information (specifically letter-identity, which is graphological in Gibson's theory) become available at about the same time, whether or not both are required by the task. Then, the subject uses phonological information for access to meaning. This would appear to be (at least as far as letter-identities and phonemic representations are concerned) an operationally parallel system.

Interestingly, while Gibson seems to stress the order of availability of types of information more than Neisser, both are willing to accept considerable changes in the importance of different types of information from moment to moment as the task demands, through postulated attentional mechanisms. One example given frequently in the literature is the subject's ability to distinguish the meaning of homophones such as "two" and "too". This ability is cited by some as a proof that access to meaning need not be mediated phonemically, but can also proceed directly from visual information. The difficulty with this as an explanation of normal reading is that it assumes that subjects are able to decide before they know that there is no phonemic difference between 'two' and 'too' that they should proceed directly to analyze for meaning, and ignore phonemic analysis. Moreover, the demonstration that subjects can do this does not mean that this is their usual strategy for non-homophones as well.

The contention of this thesis is that there are limits on the flexibility with which the subject can concentrate on one type of information and ignore other types. The experiments to be described show that subjects cannot ignore letter-identity information when processing phonemic information from written.

words. The explanation for this which will be proposed as preferable is that letter-identity information is processed before phonemic information; in Neisser's terms, the processing stages in the tasks I will describe are apparently organized as a sequential system, rather than as an operationally parallel system.

Discovering the Interaction of types of Information Processing

In the method of simultaneous comparison used in the experiments which follow, four types of processing are presumed to occur. The first type is information extraction by feature-analytic mechanisms; presumably the same types and combinations of analytic mechanisms used in reading and tachistiscopic recognition are employed here as well. Then, mechanisms compare the results of this information analysis for the two word-stimuli. (It is improbable that such comparison would occur at a feature-analytic level, where the features might be such as "straight vertical segment at the same position in both words"; such a between-words feature would be unlikely to play as large a role in this task as within-word features, and so is a doubtful alternative). A decision mechanism then evaluates the results of the comparison process and initiates response processes. When more than one type of information needs to be processed, more than one comparison mechanism may be operating, in which case the decision mechanism evaluates the output of each comparison. Presumably the decision mechanism and response processes do not change from task to task; what does change from task to task is the types of information processed and the comparisons made.

In this section, several methods for examining the relationships between these types of information processing will be described, including a novel method which examines the transfer of practice.

1) Measuring time to process.

One way of determining the ordering of types of processing is to measure how long it takes to make decisions based on each type of information. Craik (1972) has used this method to infer the order in which types of information become available from the same word, as have Posner and Mitchell (1967). The argument is that a task which takes longer is performed at a deeper level of processing. This argument can be rejected because some tasks which require very long times are likely based on <u>iteration</u> of processes at the same level; hence time to process may be as much a measure of the amount of iteration as of the depth of processing. Also, in comparison tasks, a fast extraction process may be followed by a slow comparison stage for one task, while for another task, a slow extraction process may be followed by a fast comparison stage, making overall time to compare a poor indicator of the time to extract information.

A more promising line of attack is to measure the interdependence of types of processing (usually with an eye to establishing the existence of independent successive processing stages). Sternberg's (1969) method of additive factors comes to mind at once, but it is not a suitable tool for these studies of word recognition for two reasons. It assumes that stages will be stochastically independent, and that their outputs will not be influenced by experimental factors. From the accounts of word-processing given earlier, it seems that neither of the conditions need be met by word processing. Furthermore, additive factor results can arise even if factors affect the same stage under certain (admittedly improbable) conditions. Finally, the method cannot order stages. While Sternberg's method is ideally suited to measuring reaction time, Baron (1973) has reported a complementary method for discovering the dependence of one type of information on another by measuring the accuracy of performance of the component parts of a conjoint task as a function of one another. This method seems more promising, and should be pursued when the time comes to examine internal thresholds in reading; however, the methods which were used in these investigations differed from Baron's method, and will now be described.

2) Garner's method: the effect of "irrelevant" information.

Garner (1970) has described a method of evaluating whether the subject treats two types of information independently, or "integrates" them. The basic notion is that when a subject is given a task in which one type of information is designated for attention, other types of information may tend to affect performance of that task. For example, if a pair of stimuli are to be compared for chroma, we may examine how the sameness or difference of saturation of the two stimuli affects decisions about the chroma difference. For some types of information the following pattern of results is found: subjects take longer to judge pairs of stimuli as identical for the designated information when the additional information in the stimulus pairs differs than when it matches for the two stimuli. They also take longer to judge pairs of stimuli as different for the designated information when the additional information matches than when it differs. This occurs because subjects integrate the designated and the additional information when they make their decision, and disparity between the results of comparing designated information and comparing additional information takes additional time to resolve. This method is ideally suited to the type of word-comparison task proposed here; indeed Baron (1974) has already used such a method to demonstrate that subjects do not use phonemic information to perform a comparison of visual appearance. In this thesis, the method is extended to examine the effect of phonemic information on letter-identity comparisons and vice-versa. Where Garner is concerned with mutual interference, we are concerned with the availability of one type of information at the time another is used for decisions.

3) Cohen's method: monitoring one or two types of information.

Cohen (1970) determined whether the requirement that subjects monitor stimuli for additional information affects the time to process for a designated type of information. She had subjects search prose for letters (visual targets), phonemes (phonological targets), words of a category (semantic targets), or combinations of these three types of targets. The data of interest are the relative times to search for a given target alone and in concert with another target of a different type (for example, searching for the letter "g" and the name of an animal). Cohen's results need not concern us, but the method is applicable to comparison of words. The rationale is that it should take no longer to compare a pair of two stimuli for a designated type of information when they also must be compared for a type of information which becomes available during the course of processing for the designated information. However, should there be an increase in processing time for the conjoint task, it indicates that the additional monitoring of information involves additional processing which does not occur during processing for the designated information alone. (Note that it may be that the additional comparison stage required in the conjoint task may also add to total processing time, and this must be controlled for, or taken into account.) A further argument can be made when monitoring of one type of information takes longer when a second type must also be monitored, but the converse does not hold (i.e. it takes no longer to monitor the second type of information alone or in concert with the first). This argument is that the first type of information becomes available during the course of processing for the second, but the second does not become available during the processing of the first. Such an argument leads to the tentative conclusion that the first type of information depends on earlier processes than the second. This argument can be made when either the extraction processes or the comparison processes are considered.

4) A Novel Transfer method.

The third and final method employed in this thesis is based on the fact that word processing improves with practice on a particular word or set or words, as Goldscheider and Müller demonstrated before the turn of the century (Huey, 1908). In a word-comparison task, practice could improve the comparison processes and the information analysis processes. The latter, of course, are of primary interest; it should be possible to ensure that practice is given specifically to these processes by first giving subjects considerable practice on comparison of other stimuli, before giving practice with specific stimuli which are to be studied. The interesting data will not be the existence of a practice effect <u>per se</u> for a given type of information processing, but rather the <u>transfer</u> of practice from a task requiring one type of information to a task requiring another type.

This method depends on what has been described as the "principle of inclusion" (Briggs, 1969), which states that transfer will be high if the training task included most or all of the requirements of the transfer task, but transfer will be low if the training task includes only a few requirements of the transfer task. Thus, two tasks which depend on the same processes will show high mutual transfer, while two tasks which demand different processes will show little mutual transfer. Of concern here is the pattern of transfer which will result if one task depends on a subset of the processes on which another task depends. There will be high transfer from the latter task to the former, but less transfer in the other direction. There may be as much transfer from a given amount of practice on performance on the more complex task to the less complex as there is from an equal amount of practice on the less complex task itself. But there will be less transfer from the less complex task to the more complex than there is from equal practice at the more complex task itself.

The demonstration of such differential transfer between tasks indicates that one task depends on a subset of the processes on which another task depends. One such relationship is that between a task depending on a given set of stages, and another task depending on all these stages plus an additional stage succeeding the others. A pattern of transfer like that described is therefore an indication that performance on the tasks being studied might be explained by a successive stage model of processing (though of course other models as well could handle such a result).

Use of the three methods

In the following chapters, the last three methods are employed to examine the view that word-processing is less flexibly performed than one might assume from the problem-solving perspective. To reiterate the "hypothesis" that will be tested, it is implicit in some theories of word processing that subjects can readily ignore one type of information conveyed by a word when another type is required by a task.

Chapter III describes experiments using Garner's method to show that, while subjects can usually ignore phonemic information when comparing letter-identities, they cannot ignore letter-identity information in at least one situation where it would be helpful to do so. This inflexibility is explored in more detail in Chapters II and IV.

Chapter II describes three experiments based on the extension of Cohen's method, which find thct it takes no longer to compare words for both letter-identity and phonemic representation than for phonemic representation alone, but both of these tasks take longer than to compare words for letter-identity. This suggests that letter-identity becomes completely available sooner than the phonemic representation of a word in these experiments.

Furthermore, Chapter IV examines transfer between letter-identity tasks and rhyme tasks and finds that there is high transfer from phonemic processing to letter-identity processing, but low transfer from letter-identity processing to phonemic processing. This suggests that letter-identity processing occurs completely during phonemic processing, but that the converse is not necessarily true.

If letter-identity processing occurs completely during phonemic processing, and if the results of letter-identity processing become available before the results of phonemic processing, it is easy to see that letter-identity information could have a profound influence on tasks depending on phonemic information, while the converse might not be true. Letter-identity information would be available at the time that a decision was made on phonemic information, and discrepancies between the types of information could result in errors or delays of decision. On the other hand, phonemic information would not (or seldom) be available at the time that a decision was made on letter-identity information; hence there would be few if any occasions on which descrepancies between the two types of information could have any affect on accuracy or latency of response.

It is concluded on the basis of these three types of experiment that the flexibility hypothesis does not describe well the types of word-processing reported here, and that instead we should consider models in which some types of information are relatively difficult to ignore, no matter what the task.

CHAPTER TWO

The Effect of the Requirement of Additional Processing

In this section, three experiments are described which examine the effect of requiring the subject to process pairs of stimuli which can be differentiated on the basis of visual features and letter-identity, not only for that information, but for phonemic information as well; pairs of stimuli are also considered which can be differentiated on the basis of phonemic information alone, but must also be processed for visual features and letter-identity. It is found that the requirement of additional phonemic processing increases the time to respond to visual feature and letter-identity similarities and differences, but that there is no corresponding increase in the time to respond to phonemic similarities and differences when additional visual feature and letter-identity processing is required. It is argued therefore that the necessary visual feature and letter-identity information become completely available during the course of phonemic processing, but not conversely.

EXPERIMENT 1

Experiment I was designed to determine whether the requirement that a subject process a word for visual identity as well increases the time to process a word for phonemic identity, and similarily whether the requirement that he process for phonemes as well increases the time to process for visual identity.

If phonemes become available during the course of processing visual features and letter-identity, it should take no longer to decide that the pair of words BEAR DEAR does not rhyme when the subject must respond positively to words which rhyme and have the same 3 terminal letters than when he must merely decide whether the words rhyme, because disconfirming phonemic information should become available at the same time in both cases. Similarily, it should take no longer to decide that the pair of words BORE SOAR do not have the same 3 terminal letters when the subject must also decide whether the words rhyme and respond positively only to rhyming words with the same terminal letters than when he need only respond to letter-identity information.

METHOD

Subjects. 16 subjects, all of whom had extensive experience with the apparatus and tasks in this experiment, performed in one twenty-minute experimental session. All were ignorant of the purpose of the experiment.

Apparatus. A Tektronix 603 oscilloscope with fast-decay phosphor was driven by a PDP-8L digital computer to plot pairs of word stimuli. The display stimuli were pairs of 4-letter words, plotted using a matrix subroutine which drew letters with a height of 1 cm and a width of .75 cm in such a fashion that all points were equally bright from display to display (though a display consisting of optically dense letters with many points such as the letter M would emit more light than one consisting of fewer points, such as the letter I). A response panel equipped with microswitch buttons was connected to the interrupt bus of the computer.

The computer control program read stimulus tapes into memory at the start of each experimental block; thereafter a subject-initiated teletype response randomized the order of presentation of the stimulus pairs; after a brief interval, the first trial began.

Procedure. Subjects sat approximately 1 meter from the display scope in a darkened room. After he had accustomed his eyes to the surrounding darkness, the subject pressed a teletype key which initiated the randomization routine; after a brief delay (depending on the length of stimulus list) the first pair of stimulus words was displayed on the screen for 4.096 seconds, or until the subject pressed a response key sooner; after either of these events, the computer terminated the display, and recorded the subject's response and reaction time in milliseconds if there was a response. Then, after a 1 second delay, the next pair of stimulus words was presented.

Subjects were instructed to respond as rapidly as was consistent with accurate performance; those subjects who had run in previous experiments and had shown undesirably high error rates were instructed to increase their accuracy by responding less rapidly if possible.

In the present experiment, there were three conditions: a letter-identity condition, in which subjects compared the identity of the terminal letters in word pairs; a <u>rhyme</u> condition, in which subjects decided whether the words both rhymed, and a <u>letter-identity + rhyme</u> condition in which subjects decided whether the words both rhymed and had the same terminal letters or not.

<u>Letter-Identity Condition.</u> Pairs of 4 letter words (all of which rhymed with "or") had to be compared for the identity of the terminal 3 letters in each word. The words used were BOAR, ROAR, SOAR, and CORE, GORE, MORE. There were 6 instances of each of the possible permutations and combinations of words which would result in the same terminal letters, for a total of 36 'same' pairs, and 4 instances of each of the combinations of words with different terminal letters for 36 'different' pairs. The choice of the terminal 3 letters for comparison was made so that the portion of the stimulus to which the subject would principally attend would be the same as that required of the rhyme task.

<u>Rhyme Condition.</u> Pairs of words had to be compared for rhyme, when all words had the same terminal 3 letters "ear". The words used were BEAR, PEAR, WEAR, and DEAR, FEAR, HEAR. Pairs of words either rhymed e.g. BEAR PEAR) or did not (e.g. BEAR DEAR). The words were combined in pairs as for the letter-identity condition so that there were 36 rhyming pairs and 36 pairs that did not rhyme.

<u>Letter-Identity + Rhyme Condition.</u> Pairs of 4 letter words had to be compared for both letter-identity and rhyme. The words used were those from the letter-identity task and those from the rhyme task. Subjects saw just the same pairs they had seen during the letter-identity task

and during the rhyme task, but there were half as many instances of each possible pair in order that the list size be the same in this condition. 36 pairs thus had the same terminal 3 letters and rhymed (e.g. BEAR PEAR, BOAR SOAR), while 18 pairs had different terminal letters but still rhymed (e.g. BOAR GORE) and 18 had the same terminal letters but did not rhyme (e.g. BEAR DEAR). Subjects responded 'same' only to pairs which had the same terminal letters and rhymed, and 'different' to all other pairs. Thus subjects in this condition were exposed to just those pairs they had already seen in other conditions, but with additional processing requirements.

4 subjects performed conditions in the order letter-identity, rhyme, then letter-identity + rhyme; another 4 performed conditions in the order rhyme, letter-identity, then letter-identity + rhyme. 4 subjects performed conditions in the order letter-identity + rhyme, letter-identity, then rhyme; the remaining 4 subjects performed in the order letter-identity + rhyme, rhyme, then letter-identity.

RESULTS

Reaction times for trials on which the subjects responded within 4.096 seconds are reported here (error rates averaged 6% across all conditions). Table 1 shows the mean of the reaction times for the 16 subjects to the stimulus pairs which were seen in both the letter-identity condition and the letter-identity + rhyme condition. Such stimuli are responded to more slowly in the letter-identity + rhyme condition than in the letter-identity condition; this is true for both stimuli requiring 'same' responses like BOAR SOAR ($p < .001$, $t = 7.27$, $df = 15$) and for stimuli requiring 'different' responses like BOAR GORE ($p < .001$, $t = 4.29$, $df = 15$).

Table 1 shows the reaction times for the stimuli that were seen in both the rhyme condition and the letter-identity + rhyme condition. Such stimuli are responded to at least as rapidly in the letter-identity + rhyme condition as in the rhyme condition; this is true for both the stimuli requiring 'same' responses such as BEAR PEAR ($p > .10$, $t = 0.39$, $df = 15$) and for stimuli requiring 'different' responses such as BEAR DEAR ($p > .10$, $t = .87$, $df = 15$). In fact, in the latter cases, the observed differences are in the direction that letter-identity + rhyme is performed slightly faster than rhyme alone.

Note that the same response is required of a given stimulus in both of the conditions in which it can occur; the response to BOAR SOAR, for example, is the same in the letter-identity task and the letter-identity + rhyme task, and that to BEAR PEAR is likewise the same in the rhyme task and the letter-identity + rhyme task. Thus, subjects who had performed the letter-identity task and the rhyme task before they performed the conjoint task had practice on the correct responses for the conjoint task, since there was no change in stimulus-response contingencies. The fact that subjects already knew the responses to the letter-identity stimuli might be expected to eradicate any effect of additional phonemic processing. However, when the 8 subjects who performed the conjoint task on letter-identity + rhyme last are considered alone, the pattern of results is identical to that for the subjects as a whole. Thus practice in assigning responses to the letter-identity stimuli does not eradicate the increase in time due to the requirement that phonemic information be monitored.

DISCUSSION

Processing words for rhyme as well as visual identity takes longer than processing for visual identity alone, but no longer than processing for rhyme alone. The change in the time it takes to reject words with a visual feature and letter-identity difference when rhyme must also be considered is not consistent with the notion that letter-identity and phonemes become available concurrently, no matter whether the task requires it or not. Because processing words for rhyme takes no longer when they must also be processed for letter-identity, it seems likely that subjects have letter-identity information available during processing for rhyme. This in turn militates against the possibility that subjects process only phonemic information for the rhyme task, and only letter-identity information for the letter-identity task, and must perform the two types of processing independently and sequentially during the letter-identity + rhyme task. If such were the case, we would predict an increase in the time or a decrease in the accuracy of performance for <u>both</u> types of processing when both must be performed at once, because of uncertainty about which type of information will be crucial to the decision in the letter-identity + rhyme condition (Kristofferson, 1969), assuming limited capacity in this sense.

The results might also be attributed to an increase in mutual confusability between the possible stimuli because there are additional alternatives in the letter-identity + rhyme condition; again, such an effect should be observed for both the stimuli used in the letter-identity condition and those used in the rhyme condition, but is not found for those used in the rhyme condition.

Since the phonemic similarity between non-rhyming pairs such as BEAR/DEAR may be greater than the letter-identity similarity between differently-spelled pairs such as BOAR CORE, it could be argued that phonemic processing takes longer than visual feature processing and letter-identity analysis, not because phonemic processing takes longer in general, but because in this instance, it takes longer to compare highly similar stimuli than to compare dissimilar stimuli. As it is hard to judge a priori the relative difficulty of phonemic and visual feature/letter-identity judgements, the import of this point is doubtful. In any case, the stimulus set used in a subsequent experiment circumvents this problem, as will be seen in the discussion of Experiment III.

So processing for rhyme as well as letter-identity increases the time it takes to respond to letter-identity information, but not the time it takes to respond to rhyme information. It would seem, then, that letter-identity information can readily become available during phonemic processing, but phonemic information is not so readily available during letter-identity processing.

EXPERIMENT 11

Because the word pairs in Experiment 1 consisted entirely of upper case letters, subjects could have relied largely or entirely upon a visual matching strategy (Eichelman, 1970) in the letter-identity condition. That is, when features matched for the last part of each word in a pair, the subject could safely respond "same"; contrarily, when features did not match, subjects could respond "different". This could account for the faster time to respond "different" to pairs like "BOAR CORE" in the letter-identity condition than in the letter-identity + rhyme condition if subjects were not relying on the feature matching strategy as much in the latter condition, but instead used some more abstracted representation of letter-identity which took longer to form.

If subjects could be discouraged from using a visual feature-matching strategy even in the letter-identity condition, differences between that condition and the letter-identity + rhyme condition might be reduced or eliminated. On the other hand, it would be more interesting if, even when feature-matching could not be used as a reliable strategy, subjects could nonetheless respond more rapidly to stimuli in this task than to the same stimuli in the letter-identity + rhyme task. This would indicate that the sort of parallel information extraction that Rubenstein et al postulate does not occur even when a relatively abstract form of visual information is required.

Experiment 11 was designed to discover whether or not the differences observed in Experiment 1 persisted even when feature-matching was a relatively futile strategy because the second member of each pair of words to be compared was printed in a different type case.

METHOD

Subjects. 8 subjects participated in this experiment. Most had served in previous experiments and were well familiar with the apparatus and stimuli.

Apparatus and Procedure. The same apparatus and procedure were employed as in Experiment 1, with one important change. The computer program was modified so that for each pair of stimuli displayed, the first member of the pair was printed in capital letters, while the second member of the pair was printed in lower case letters (e.g. BOAR soar, BEAR pear, etc.). Only in this respect did the stimulus pairs differ from those in Experiment 1, in which both members of each stimulus pair were printed in capitals (e.g. BOAR SOAR, BEAR PEAR). As for Experiment 1, the 3 tasks - letter-identity, rhyme, and letter-identity + rhyme - were presented to the subjects in 4 different orders; however, only 2 subjects experienced each order.

RESULTS

Though the reaction times across subjects for all three conditions are on the order of 300 milliseconds longer (for both same and different responses) in this experiment than in Experiment 1, the pattern of results is the same. Table 11 shows that subjects took longer to respond to pairs in the letter-identity and rhyme task than in the letter-identity task to the same pairs; this held both for "same" stimulus pairs ($p<.01$, $t=3.9$, $df=7$) and for "different" stimulus pairs ($p<.01$, $t=2.8$, $df=7$). However subjects did not take significantly different times to respond to pairs in the rhyme condition or to the same pairs in the letter-identity + rhyme condition. This was true both for "same" pairs ($p>.10$, $t=1.1$, $df=7$) and for "different" pairs ($p>.10$, $t=.1$, $df=7$).

DISCUSSION

Because it takes longer to respond "different" to a pair of words with different terminal letters (e.g. BOAR core) when they occur in a list in which phonemic differences must be detected even in the absence of terminal letter differences, it is difficult to maintain that the additional requirement of phonemic processing takes no time or effort beyond that normally required to ascertain letter-identities in words. This experiment indicates that even at the more abstract level of letter-identity comparison necessitated by the non-isomorphic "same" pairs produced by the use of upper and lower case letters, the requirement that phonemic differences be detected increases the time to process letter-identity information.

However, there is not a corresponding increase in the time to process phonemic information when letter-identity had to be monitored as well. This suggests that letter-identity becomes available during the course of phonemic processing, but not conversely. This can be explained by recourse to a number of models; consideration of these models will be postponed until the discussion of the results of the following experiment, however, in order that a more complete case may be made.

The slower reaction times in Experiment 11 than in Experiment 1 reinforce the notion that visual features becomes available early in the course of processing; when subjects cannot rely on visual features for matching, as in this experiment, they take longer. The explanation for this which I prefer is that accepted by many theorists today: visual feature analysis precedes other types of analysis.

EXPERIMENT III

It might fairly be objected that in Experiments I and II, subjects learn to which letter positions they need attend in order to make decisions about letter-identity and visual features, and therefore that their task is simpler than when they attend to all letters in the word to make decisions about rhyme. Therefore, it could be argued, when they must both attend to letter-identity and rhyme, the strategy of attending to specific letter-positions is unfruitful and must be abandoned, in favor of a more complete analysis - hence the increases in time to determine that words differ in letters when rhyme must also be motioned.

While this does not exclude the possibility that letter-identity and feature information become available during the course of phonemic processing, and that phonemic processing is an addendum to these other types of processing, it can be easily eliminated by using a larger stimulus set in which various word pairs differ at various letter positions. Such a stimulus set would preclude the strategy of attending to any one stimulus position in the letter-identity task. Moreover, because different stimuli were used in the letter-identity and rhyme tasks of both Experiment 1 and 11, it is possible that increased time to respond to the letter-identity stimuli in the letter-identity and rhyme condition was due to an increased confusability of the total possible stimulus set which affected the letter-identity stimuli more (or to the addition of a decision about which original list a stimulus belonged to, except that the balanced order of running subjects eliminates this explanation) - some subjects began with the combined list condition letter-identity + rhyme. Or it may be that the particular stimuli chosen for the rhyme condition (BEAR PEAR etc.) were easy to process for letter-identity, while those chosen for the letter-identity condition were hard to process for rhyme; perhaps, as suggested in Experiment 1, there were discriminability differences.

To eliminate the possibility that differences in time to respond to stimuli in the 3 conditions of Experiment 1 and 11 depend on differences in stimuli used in the different conditions and on specific letter differences, Experiment 111 was performed, using a stimulus set which could be employed in all 3 conditions; of letter-identity comparison, rhyme comparison and letter-identity + rhyme comparison and in which various pairs of stimuli differed in various stimulus locations. As in Experiment 11, feature matching was discouraged by showing the left member of each pair in capital letters and the right member in lower case letters. Moreover, the stimulus set was chosen so that there were 14 replications of the basic stimulus conditions; analysis could therefore be performed between stimuli as well as between subjects.

METHOD

<u>Subjects.</u> 16 subjects, most of whom had participated in previous experiments and were familiar with the experimental apparatus and stimuli, each ran in all three conditions in one day.

<u>Apparatus and Procedure.</u> The same control program and apparatus were used as for Experiments 1 and 11, with the modification that subjects could initiate rest periods during an experimental session, by not releasing the button used to make a response. As long as the response button was held down, timing of the blank interval preceding the next trial did not begin. As it happened, only one subject since reported using the rest interval option - and then only out of curiosity.

However, the stimulus lists were such that the same stimulus pairs occurred in all 3 conditions. 14 groups of words were selected by choosing a pair of homophones (e.g. FOUR FORE) and another pair of words which differed in the same letters, but were not homophones, with the constraint that one of the words in this letter pair must rhyme with the homophone pair. Four different pairs of stimuli can be constructed by pairing a word from the homophone pair with a word form the non homophone pair. One pair has the same terminal letters and rhymes (FORE SORE); another pair has the same terminal letters but does not rhyme (FOUR SOUR); a third pair has different terminal letters and rhymes (FOUR SORE), and the remaining pair has different terminal letters and does not rhyme (FORE SOUR). Table 111 a shows the 14 pairs of homophones and the 14 pairs of corresponding non homophones used in the experiment. Each pair of stimuli combined can occur in two orders (e.g. FOUR SOUR, SOUR FOUR), so there were a total of 112 different stimulus pairs available (4 pairs per group X 2 orders for each pair X 14 groups of stimuli). There are 28 pairs that have the same terminal letters (LS), and rhyme (SS), 28 pairs that have the same terminal letters and don't rhyme (SD). 28 pairs that have different terminal letters (LD), and rhyme, and 28 pairs that have different terminal letters and do not rhyme.

The three experimental conditions were the same as in Experiment 1 and 11:

(1) Letter-Identity Condition: Subjects were instructed to respond "same" to pairs which had the same terminal letters (e.g. FOUR SOUR), and "different" to other pairs (e.g. FOUR SORE). Some words had only two letters - subjects were instructed to respond only to the final letter; others had 3 letters - subjects responded to the last 2 letters; words with 4 or 5 letters were compared for the last 3 letters. All 112 stimuli were used for this condition providing an equal number of LS (letters same) and LD (letters different) pairs.

(2) Rhyme Condition: Subjects were instructed to respond "same" to pairs which rhymed (e.g. FORE SORE, FOUR SORE) and "different" to others pairs (e.g. FORE SOUR, FOUR SOUR). Thus, some of the pairs to which subjects were required to respond "same" in the

letter-identity condition now required a "different" response, because, though their terminal letters were identical they did not rhyme (e.g. FOUR SOUR). Likewise, some pairs which required a 'different' response in the letter-identity condition now required a 'same' response because, although their terminal letters differed, they rhymed (e.g. FOUR SORE). As for the letter-identity condition, all 112 stimuli were used, providing an equal number of rhyming and non-rhyming pairs.

(3) Letter-Identity + rhyme Condition: Subjects were instructed to respond 'same' to pairs which both rhymed and had the same terminal letters (e.g. FORE SORE), and 'different' to all other pairs (e.g. FORE SOUR, FOUR SORE, FOUR SOUR) which were non-rhyming, differed in terminal letters, or both. As well as the 112 stimuli employed in the other two conditions, 56 additional stimuli were used, consisting of 2 instances each of the 28 stimulus pairs which rhymed and had the same terminal letters. This provided an equal number of stimuli requiring 'same' responses (84 word pairs) and 'different' responses (84 word pairs).

Note that this list differs from the one used in the other two conditions in terms of the probability of a given type of pair, because the LS-SS pairs such as FORE SORE occurred 3 times as frequently as the other pairs. This gives the subject more practice with certain of the words than with others; specifically, there are fewer occurrences of the words in the LD-SD pairs such as FOUR SOUR. While this might be expected to influence the results seriously if protracted practice at the letter-identity + rhyme condition were given, the large stimulus set was expected to make the effects of this differential probability relatively unimportant.

Neither the letter-identity task, the rhyme task, nor the letter-identity + rhyme task can be performed by attending to the first letters of the stimulus words, since for each stimulus group all pairs have the same pattern of first letters (e.g. for the first group, all pairs are such that one word begins with F, the other with S).

Each subject ran in all 3 experimental conditions during one half-hour experimental session. The same 4 orders of presentation of the conditions were employed as in Experiments 1 and 11.

RESULTS

Reaction times shown in Table 111 for the letter-identity and the letter-identity + rhyme conditions were compared for all stimuli save those which had the same terminal letters but did not rhyme (LS-SD) - because such pairs required a "same" response in the letter-identity task but a "different" response in the letter-identity + rhyme task. The pairs which rhymed and had the same terminal letters (LS-SS) took longer to respond to in the letter-identity + rhyme condition ($t=3.89$ $df=15$), as did pairs which rhymed and had different terminal letters (LD-SS; $t=3.52$, $df=15$). Note that the LS-SS pairs and the LD-SS pairs in this experiment correspond to pairs like BOAR SOAR and BOAR CORE respectively in Experiments 1 and 11, and that the pattern of results obtained here is the same as in those experiments for such pairs. There was another possible comparison between the letter-identity condition and the letter-identity + rhyme condition in this experiment that was not possible in Experiments 1 and 11. This was for the non-rhyming pairs that had different terminal letters (LD-SD), and as for the other two comparisons, the LD-SD pairs had longer response times in the letter-identity + rhyme condition (t=3.27, df=15). As the appendix shows, none of the corresponding error rates comparisons differ significantly; the average error rate for these stimuli was 6%.

Table 111 also shows reaction times for the rhyme condition. The LS-SS pairs did not take reliably longer to judge in the letter-identity + rhyme condition (t=.64, df=15); the same is true for the LS-SD pairs (t=.67, df=15). Note that the LS-SS pairs correspond to pairs like BEAR PEAR in Experiments 1 and 11, while the LS-SD pairs correspond to pairs like BEAR DEAR, and that the pattern of results for these pairs is the same. There is a new comparison that was not possible in those experiments, for LD-SD pairs, and in this experiment such pairs were responded to considerably faster in the letter-identity + rhyme condition than in the rhyme condition (t=5.16, df=15). As the appendix shows, there were fewer errors in the letter-identity + rhyme conditions for both LS-SD pairs and the LD-SD pairs, but not for the LS-SS pairs. The LD-SS pairs were not compared for either reaction time or error rates, because such pairs required a "same" response in the rhyme condition, but a "different" response in the letter-identity + rhyme condition.

The same pattern of results occurs when data is analyzed across the 14 word-groups (FORE SORE, FOUR SOUR, FOUR SORE, and FORE SOUR make up one word group of LS-SS, LS-SD, LD-SS, and LD-SD pairs, respectively) rather than across the 16 subjects. This reduces the likelihood that the results are due to idiosyncratic stimulus-pair differences. (See the Appendix for this analysis).

The question raised in the introduction to this experiment about the increased frequency of LS-SS pairs in the conjoint task, and the correspondingly higher frequency of occurrence of words in such pairs than in the LD-SD pairs, can now be considered briefly. The pattern of effects for the LS-SS pairs is the same in this experiment as in Experiments 1 and 11, suggesting that the possible extra practice did not obliterate or create any effects for the LS-SS pairs. This in turn renders it unlikely that the lower relative frequency of LD-SD pairs in the conjoint task produced the pattern of results, especially when it is considered that the LD-SD pairs took less time to be responded to in the conjoint task than in the rhyme task, despite a lower relative frequency of occurrence in the former task.

DISCUSSION

The results of Experiments 1 and 11 might be due to the small stimulus set and relative difficulties of comparison for the letter-identity pairs and the rhyme pairs, but an identical pattern of results is found in this experiment, which used a large stimulus set, in which not all "different" stimulus pairs differed in the same positions, and in which the same stimuli are used for all conditions. Thus it cannot be argued that the stimuli in the 'rhyme' condition differ for rhyme more than those in the letter-identity condition, and thus are easy to compare in the letter-identity + rhyme condition.

An interesting comparison is that for the pairs of stimuli which differ both in terminal letters and in rhyme (LD-SD). In the letter-identity + rhyme condition, such pairs can be rejected as different on either or both of two grounds, so it is not too surprising that they take less time to compare in the letter-identity + rhyme condition than in the rhyme condition. What is surprising is that they take longer to compare in the letter-identity + rhyme condition than in the letter-identity condition; clearly the additional information that LD-SD pairs do not rhyme does not speed the decision relative to a decision based on visual feature and letter-identity information alone. This renders unlikely the explanation that letter-identity information and phonemic information are processed completely, concurrently, and independently, and then are combined for a decision in the letter-identity + rhyme condition.

One possibility is that the subject responds "different" in the letter-identity + rhyme condition as soon as either letter-identity or rhyme information become available, and that letter-identity information becomes available before rhyme information. This explanation is supported by the fact that response times are greater for the same stimuli in the rhyme condition than in the letter-identity condition. However, if letter-identity information is available before phonemic information, then for LS-SD pairs, the information that the two words have the same terminal letters could be available before the information that they do not rhyme. A "competing response" or "conflicting cues" position (cf Kreuger, 1973) would predict that such pairs would have longer response times or more errors when letter-identity is monitored and can provide conflicting cues than when it is ignored, and only rhyme is considered. Thus the times for LS-SD pairs in the letter-identity + rhyme condition should be longer than in the rhyme condition; instead, the error rate is lower and reaction time not significantly different in the letter-identity + rhyme condition than in the rhyme condition. This makes the competing response explanation unlikely. However, it is consistent with the possibility that the subject responds 'different' as soon as either letter-identity or phonemic differences in the crucial locations are detected.

STRATEGIES

This section describes some strategies subjects might have used to perform the experiments just reported. Simple sequential processing and parallel processing models are inadequate, but with modifying assumptions both will serve. Interestingly, the modifying assumptions for both models involve capacity sharing.

1) Consider some of the strategies which subjects may pursue in performing the letter-identity + rhyme task. One is to attend to both types of information, and respond "different" as soon as a mismatch occurs for either type, and "same" as soon as processing is exhaustive. This explanation accounts readily for the performance on the LD-SD pairs in the rhyme (R) and letter-identity + rhyme (LI + R) conditions, and for performance on the LS-SS pairs in the LI and LI + R conditions. But to account for the difference between the LD-SS pairs and the LD-SD pairs in the LI and LI + R conditions, we must also assume that it takes longer to detect and respond to a letter-identity difference when rhyme must also be monitored than when rhyme can be ignored. A competing response

explanation can be rejected, since, though it would account for longer times for the LD-SS pairs in the LI + R condition, it would not predict longer times for LD-SD pairs.

Longer times to detect and respond to letter-identity <u>differences</u> when rhyme must also be monitored might arise in a number of ways. First, subjects may process stimuli exhaustively for both letter-identity and rhyme, no matter if differences are detected for either type of information. If letter-identity processing occurs before phonemic processing, or operates concurrently but is completed before phonemic processing, then response to all pairs which require the same response in both conditions - LS-SS, LD-SD, and LD-SS - will take longer in the LI + R condition than in the LI condition. However, there will be no difference in the time to respond to all pairs which require the same response in both conditions (LS-SS, LS-SD, LD-SD) between the LI + R condition and the R condition. This strategy was not adopted either, because subjects take less time to respond to LD-SD pairs in the LI + R condition than in the R condition.

ii) A second strategy would be to process for letter-identity first; then, if there is a difference, respond "different"; if there is no difference, process for rhyme information. If this strategy were adopted, it would take no longer to respond to LD-SS pairs and LD-SD pairs in the LI + R condition than in the LI condition, because subjects could respond correctly purely on the basis of letter-identity information for these pairs. This second strategy, then, was not adopted by subjects in these experiments.

iii) A third strategy would be to process both rhyme and letter-identity information simultaneously, and respond as soon as a difference is found, or if both types of information match. Such simultaneous processing could have several different effects on performance, depending on whether or not capacity sharing occurs in the LI + R task, and whether or not the L tasks and R tasks are performed quite differently than the LI + R task. If there is no capacity sharing in the LI + R task, then there should be no effect on the time to process and compare letter-identity information in this task in relation to the LI task. As already indicated, times to respond to LD-SS and LD-SD pairs in the LI + R task, LI + R task are longer than in the LI task. If there is capacity sharing in the LI + R task, it will be asked, then why is there no corresponding increase in times to respond to LS-SD pairs and LD-SD pairs in the LI + R task compared to the R task? One answer is that there _is_ capacity sharing in the LI + R task, but that the same capacity sharing occurs in the R task as well, because letter-identity information is processed in that task as well. Letter-identity information could then be processed in the rhyme task, not because the experimenter requires it, but because it is a necessary if not sufficient part of the strategy of phonemic processing.

IV) A fourth strategy is related to the second and third strategies: the subject processes first for letter-identity information, then for phonemic information. There is an increase in the time to process for letter-identity information because phonemic processing begins when letter-identity processing is partially completed, and robs capacity, slowing down the completion of the letter-identity task. In the letter-identity task, the subject need not devote attention or capacity to phonemic processing at all, and so he never utilizes partial letter information to begin phonemic processing. In other words, in the LI + R task, even though the subject may decide about letter-identity before he can decide about rhyme, he must begin to process phonemically before he can make a response based on letter-identity. It is this preparation for the possibility of subsequent phonemic processing which slows his response, even to pairs which turn out not to need the provision.

Of the four strategies described, only the last two could account readily for the results of the preceding experiments. The third strategy, simultaneous processing of rhyme and letter-identity, will subsequently be shown to be more <u>ad hoc</u> than the last strategy, which calls for the subject to process first for letter-identity, then for phonemic representation.

CHAPTER THREE

The Effect of Additional Information when not Required

Experiments I, II and III examined the effects of the requirement that subjects process for more than one type of information on the time to process a given type. In other words, the subjects were forced by the task to attend to now one, now another, now both types of information. The experiments in this section examine the effects of information to which the subject was not required to attend on performance of tasks depending upon other information which was designated by the experiments. The rationale is that if subjects can make use of non-designated information, such information becomes available during the course of processing for the designated type. If non-designated information has no effect on responses, two possibilities must be considered. The first is that the non-designated information is not processed during the course of processing for the task; the second is that, though processed, it is suppressed or ignored at the time of making a decision about the designated information. The results of Experiments I, II and III lead us to expect that letter-identity information should have an effect on decisions about phonemic information, and as will be seen this is the case. In general, however, phonemic information does not effect decisions about letter-identity in the tasks studied here, except under stimulus conditions which produce long response latencies, and may encourage reliance on memory mechanisms.

Experiments IV and V examine the influence of letter-identity information on phonemic comparisons; Experiments VI to IX look at the converse, that is, the influence of phonemic information on letter-identity comparisons.

EXPERIMENT IV

In the light of the results of Experiments I, II, and III, it seems likely that visual features and letter-identity information become available at an earlier time during processing than does phonemic information. It would be expected, then, that subjects could make use of such information during phonemic processing to aid rhyme decisions, or even use such information in place of phonemic information.

Eichelman (1970) showed that a subject can rapidly decide that two words have the same letter-identities when both are printed in the same case (TORE TORE) and feature matching is possible, but that it takes longer to decide that letter-identities are the same when feature matching is not possible because one word is printed in upper case type and the other in lower case type (e.g. TORE tore). Interestingly, it took longer to decide that a pair of words did not have matching letter-identities (e.g. TORE LEND) when such pairs occurred in lists which had words printed in different cases and could therefore have matching letter-identities despite feature mismatch, than when such pairs occurred in lists in which all words were printed in the same case, and therefore a feature mismatch meant a letter-identity mismatch as well. In combination, these results indicate that feature matching occurs before letter-identity matching, and that subjects perform letter-identity matching when feature matching is unreliable (although a feature match always means a letter match in his experiment).

Experiment IV was designed analogously to the experiment of Eichelman, in order to determine whether subjects could learn to use letter-identity information to aid in a rhyme task, and if so, whether that information became available sooner than phonemic information and therefore speeded identification of rhyming words with letter-identity matches.

METHOD

Subjects: 8 paid subjects each performed the two experimental conditions in a single half-hour session.

Apparatus and Procedure: The apparatus and procedure for presenting lists of pairs of 4 letter words described for Experiment II were used unchanged for Experiment IV. In both experimental conditions, subjects were required to respond as rapidly and accurately as possible after deciding whether the pair of words displayed on the oscilloscope rhymed or did not rhyme.

In the congruent condition, letter-identity information was always sufficient to decide whether or not a pair of words rhymed. That is, if a pair of words differed in the last 3 letters (e.g. BARE deer), they did not rhyme, but if identical in the last three letters (e.g. BARE dare) they rhymed also. Thus letter-identity information and phonemic information were congruent in this task, and so it is analogous to the 'pure' condition in Eichelman's experiment in which feature information was always correlated with letter-identity.

On the other hand, in the non-congruent condition, as well as the stimulus pairs used in the congruent condition, there were additional stimulus pairs, some of which rhymed yet differed in letter-identity, and others of which did not rhyme, yet had the same difference in terminal 3 letters. Thus letter-identity information and phonemic information were not congruent in this task, and so it is analogous to the 'mixed' condition in Eichelman's experiment in which feature information was not congruent with letter-identity. Subjects were not informed of the congruency (or lack of congruency) until after the experimental session.

There were 96 stimulus pairs in the congruent condition, formed by pairing either BARE or BEER with DARE or DEER, such that in every pair, one word was printed in capitals, and the other in lower case letters; 48 of the pairs thus formed rhymed, while the remaining 48 did not rhyme. The difference in case was employed to ensure that subjects could not compare words in terms of features alone, without reference to letter-identity or phonemes.

There were 144 pairs of stimuli in the non-congruent condition, formed by pairing BARE, BEER, or BEAR with DARE, DEER, or DEAR, with one word in lower case and the other in capitals. Of the 72 pairs which rhymed, 48 were identical with the rhyming pairs of the congruent condition; likewise, 48 of the non-rhyming pairs were identical with the non-rhyming pairs of the congruent condition, while the remaining 24 non-rhyming pairs were novel.

4 subjects performed the congruent condition first, then the non-congruent condition, while the other 4 performed the two tasks in the opposite order. The subjects were instructed before each condition what the stimulus vocabulary would consist of, and the alternatives remained on a dimly lit blackboard in the experimental room to permit them to refresh their memories if necessary.

RESULTS

Table IV shows the mean of the reaction times of the 8 subjects for stimuli which occurred in both the congruent and non-congruent conditions. Both "same" and "different" pairs have appreciably longer reaction times in the non-congruent condition than in the congruent condition. ($p < .001$, $t = 6.2$, $df = 7$ and $p < .001$, $t = 9.2$, $df = 7$ for same and different stimuli respectively).

DISCUSSION

It takes longer for a subject to decide that a given pair of words rhyme when he knows he cannot rely on letter-identity information (in the non-congruent condition) than when he knows that letter-identity information is congruent with rhyme. This would be the case if subjects were suppressing letter-identity information in the non-congruent condition, and utilizing it in the congruent condition.

An alternative explanation is that subjects are performing the congruent task by attending only to letter-identity information, and the non-congruent task by attending only to phonemic information. Subjects did not report such a strategy when questioned, and indeed several reported an effect they called "phonemic satiation" during both conditions - they began to make mistakes because they could not decide what a word sounded like. Nonetheless, it may be that subjects are not attending to letter-identity at all during the non-congruent condition. In the light of the findings of Experiment 1, 11, and 111, however, this is not as likely as the explanation that letter-identity information is readily available during phonemic processing, and must be suppressed. Either explanation is consistent with other results reported in this thesis.

EXPERIMENT V

In Experiment 1V, subjects could have ignored phonemic information completely in the 'congruent' condition, and instead have relied on letter-identity information alone. Introspection by several subjects suggests that they did not do so, but Experiment V was conducted to examine performance when subjects had to attend to phonemic information to perform a rhyme judgement. Such a task would encourage subjects to ignore letter-identity information if at all possible.

METHOD

The rhyme condition of Experiment lll, which has already been described, provided the data for Experiment V.

RESULTS

Referring to Table lll again, we see that LS-SS pairs of words which rhyme and have the same terminal letters are responded to more rapidly (and accurately, as the appendix shows) than LD-SS pairs which rhyme but differ in their terminal letters (t=7.00, df=15). However, LD-SD pairs do not take significantly less time to judge than do LS-SD pairs, (t=.53, df=15), nor are they performed more accurately. These results also hold when comparisons are made across stimuli, as in Experiment lll. (See the Appendix for this analysis)

DISCUSSION

Because the same terminal letter and phonemic similarities and differences existed across stimulus conditions, it is unlikely that these results can be accounted for in terms of differential difficulty of processing a given type of information in various conditions. The results for "same sound" pairs clearly show that letter-identity differences are processed and available at the time of response to phonemic information, even though letter-identity information is irrelevent to the task at hand. Why then, are LS-SD pairs responded to no more slowly than LD-SD pairs? We would expect the contradictory letter-identity information to slow responses to the LS-SD pairs. It is possible that the discovery that a pair of words do not have the same terminal letters leads to different subsequent phonemic processing than occurs when words match for terminal letters. The subject may choose to process exhaustively for phonemes when there are also letter-identity differences. If such is the case, there would be no difference in the time to process a pair which rhymed and a pair which did not rhyme, since both will be processed exhaustively for phonemes.

<u>The effects of phonemic information on letter-identity comparisons</u>

EXPERIMENT V1

Baron (1973) found that homophone word pairs (e.g. FOUR FORE) in a visual appearance discrimination task were compared as rapidly and accurately as non-homophone pairs (SOUR SORE); because both words in each pair were printed in the same type, subjects could have relied on feature matching alone, without reference to letter-identity. However, they could equally as well have been comparing the word pairs on the basis of letter-identity, or a mixture of features and letter-identities. Baron's experiment and Experiments V11 and V111 (which will be described later) require subjects to compare all the letters in each word for identity. An experiment which compares only terminal letter groups, while not strictly necessary, would render the aforementioned experiments more comparable to the others reported in this thesis. Such an experiment was performed.

METHOD

As for Experiment V, data from Experiment III, which have already been described, were used. The letter-identity condition of that experiment is considered in more detail here.

RESULTS

The results are once more found in Table III and the appendix. Subjects took no longer to respond "different" to the LD-SS condition than to the LD-SD condition (t=.226, df=15); this comparison corresponds to Baron's finding that there were no differences between homophone and non-homophone "different" pairs. However, there was a difference between LS-SS pairs and LS-SD pairs; the latter took considerable longer to judge as "same" (t=2.81, df=15); this result may seem paradoxical in light of Baron's finding that there were no differences in the time to judge homophone and non-homophone "same" pairs. These same results hold when comparisons are made across the 14 stimulus groups, thereby rendering it improbable that the results are due to idiosyncratic stimulus-pair differences. (See the Appendix for this analysis)

DISCUSSION

One reason that Baron did not find any difference between homophone and non-homophone "same" pairs might be that both correspond to the LS-SS category in this experiment: "same" pairs in his experiment each consisted of two instances of the same word, which of course were phonemically identical. In this experiment, there <u>is</u> a phonemic difference between LS-SS and LS-SD pairs, and this difference results in longer reaction times to the LS-SD pairs, as we would expect if phonemic information tends to lead to false mis-matches which must be suppressed. This effect of phonemic information here, but not in Baron's experiment, would be simply explained in terms of the longer reaction times observed here and the side-by-side display, which could easily result in the use of phonemic information here, but in the failure to use phonemic information in Baron's case, because of the need for memory in this case.

Unfortunately, this simple explanation would predict a corresponding difference for "different" pairs, so that LD-SS pairs should take longer to judge than LD-SD pairs. Instead, the same pattern of results is found as in Baron's experiment: there is no difference between the times. It is hard to accept as explanation the suggestion that the letter-identity differences between pairs with different terminal letters are the same for LD-SS pairs and LD-SD pairs, while LS-SS pairs are more similar for letter-identity than are LS-SD pairs (i.e. that FORE SORE is easier to judge "same" than FOUR SOUR). There is an explanation which could account for the presence of a phonemic effect only for pairs that have the same terminal letters. Since the subject must exhaustively process the stimulus pair for all letters before he can decide the pair has the same terminal letters, enough information is present to permit the evaluation of phonemic information. However, as soon as a letter-identity difference is detected, the subject can abandon further processing; this means that most words with different terminal letters will not be completed evaluated for letter-identity, and therefore will not be analyzed phonemically. This explanation rests on the assumption that phonemic information cannot be evaluated if letter-identity is not known; this does not mean that a subject must have processed for all its letters before any phonemic information is available.

Another explanation which seems promising and explains the results of both Experiments V and VI depends on subjects adopting a conservative strategy in this experiment, and not responding as soon as letter-identity information is available, but waiting until they are certain of that information (this is in part suggested by the reaction times which are almost twice as long as those in Baron's experiment). Then, at the time of decision about response, subjects try to attend to "different" information from only one comparison --phonemic in Experiment V and letter-identity in this experiment. If it is easy to attend to a "different" comparison for the relevant information, but hard to attend to the absence of difference, then the presence of a difference for the irrelevant information may distract the subject only when there is no difference for the relevant information. This explanation predicts a difference in reaction times between LD-SS and LS-SS pairs but not between LD-SD and LS-SD pairs in Experiment V; it would also predict a difference between LS-SS and

LS-SD pairs in this experiment, but not between LD-SS and LD-SD pairs. Because this explanation predicts the results of both experiments, and because it is in accordance with attention theories which hold that attention tends to shift from 'channels' (sources of information) in which there is no developing information to channels in which there is information, it is a most tempting alternative. It is not inconsistent with the results of Baron's experiment, because in Baron's experiment, subjects probably did not have enough time in which phonemic information could become available. Moreover, this explanation does not demand that the subject fully process phonemic information in this experiment (which is unlikely in the light of the results of Experiments 1, 11, and 111.) It is only necessary that some phonemic processing begin before a response is initiated, and that the phonemic processing of phonemically different pairs be more demanding of attention than the processing of phonemically similar pairs.

Of course, another reason for the difference between these results and those of Baron could be that subjects need only attend to terminal letters here, but in Baron's study, had to attend to the entire string of letters. To explore this possibility more fully, the following two experiments were performed.

EXPERIMENT V11

To establish whether there is an effect of phonemic information on letter-identity discrimination (and hence whether phonemic information is present during letter-identity processing), Baron's visual comparison task was modified so that subjects were discouraged from relying on feature matching. As in Experiments 1 and 11, feature matching was made a futile strategy because the upper member of each stimulus pair was printed in capital letters, while the lower member was in lower case type. Moreover, to facilitate the letter-identity matching, words were presented one above the other, rather than side-by-side as in previous experiments. This rendered stimulus conditions more like Baron's.

METHOD

Subjects. 8 experienced paid volunteers served as subjects in a single half-hour experimental session.

Apparatus and Procedure. The same apparatus control program was used as described previously, except that the program was modified to display the two words in the stimulus pair one above the other, so that each letter in the uppermost word was directly above its positional counterpart in the lower word. The letters were also enlarged by a factor of 1½. Both of these steps were taken to ensure that the stimuli and procedure would be largely comparable to those of Baron.

There were two groups of stimuli in this experiment. 16 homophone pairs (e.g. FOUR FORE) were matched with 16 non-homophone pairs differing in the same letters (e.g. SOUR SORE). Each pair could occur in two vertical orders (e.g. FOUR above FORE, and FORE above FOUR), making a total of 32 homophone pairs and 32 non-homophone pairs which differed in at least one letter. There were also 32 pairs which matched in all letters drawn from the words making up the homophone pairs (e.g. FOUR four, and FORE fore), and 32 matching pairs corresponding to the non-homophone pairs. Therefore there was a total of 64 stimuli where letter-identities matched, and 64 pairs which did not match for at least one letter.

Subjects were presented with this list of 128 pairs 3 times, with rest intervals of several minutes between each replication of the list.

RESULTS

Reaction times (error rate, 8%) are shown in Table V by stimulus condition. As with Baron's results, there is no reliable effect of homophony on 'different' pairs (t=.28, df=15) for reaction time or accuracy; nor is there a reliable effect on a measure of the interaction of the effects of homophony with the effects of same-or-different responses. This measure is simply constructed by using performance on the 'same' pairs as a base line for performance on the 'different' pairs for the homophones and the non-homophones. That is, there should be a greater difference in reaction time between a homophone 'same' pair and their corresponding 'different' pair than between the equivalent non-homophone 'same' and 'different' pairs, if phonemic information aids the letter-identity judgement. Such is not the case: the interaction measure falls far short of significance (t=.465, df=15), as does the main effect measured between homophone and non-homophone "different" pairs.

DISCUSSION

Even when there is a visual feature difference between words and subjects must rely on letter-identity information for accurate comparison of pairs of words, phonemic differences do not influence the letter-identity discrimination. This reinforces Baron's conclusion that the visual same-different task he employed is not performed phonemically.

EXPERIMENT VIII

One reason why Baron's task is not performed phonemically might be that subjects suppress phonemic information because on some trials (for homophone pairs) phonemic information would lead to erroneous "same" responses. Therefore, Experiment VII was repeated, but with this difference: the subjects were told in advance to expect only homophone pairs in one experimental condition, and to expect only non-homophone pairs in another condition. If subjects had been suppressing phonemic information in Baron's experiment and Experiment VII, they would now be encouraged to employ it for the non-homophone condition.

METHOD

Subjects. 8 experienced paid volunteers each served as a subject in a single half-hour experimental session.

Apparatus and Procedure. The same apparatus and control program was used as in Experiment VII. However, the experimental lists differed in one important respect from Experiment VII: there was a list consisting of 128 pairs of homophonic words (2 instances of each stimulus pair from the 32 homophone pairs which differed in at least 1 letter, and 2 instances of each matching "same" pair). There was also a corresponding list of 128 pairs of the non-homophonic words.

Half the subjects performed the homophonic list twice, then the non-homophonic list twice; the other half of the subjects performed the lists in reverse order. There were brief rest periods between each presentation of a list, while data was collected from the computer; before each list, subjects were told whether or not there would be phonemic differences between the words they saw.

RESULTS and DISCUSSION

Table VI shows that, as for Experiment VII, there is no reliable effect of homophony on either the "different" pairs ($t=.334$, $df=15$) or the interaction measure ($t=.016$, $df=15$). Apparently, subjects cannot be encouraged to rely on phonemic differences in this task, short of demanding that they ignore letter-identity information and utilize only phonemic cues.

EXPERIMENT IX

Experiment VI showed that pairs of words are judged to have the same terminal letters more slowly when they do not rhyme than when they rhyme, presumably because of the phonemic information difference attributable to the terminal letters in the non-rhyming pairs. Such a comparison between rhyming and non-rhyming "same" pairs was not possible for Experiments VII and VIII and Baron's (1973) experiment, because the "same" pairs for these studies consisted of two instances of the same word, and so words in the pairs were always phonemically identical. Because there was no difference between rhyming and non-rhyming different pairs in those studies, it was concluded that phonemic information does not contribute significantly to the letter-identity comparison task; however, there was also no difference between "different" judgements for rhyming and non-rhyming pairs in Experiment VI, in which phonemic information clearly played an important role for "same" judgements at least.

This experiment was therefore performed, to decide whether the failure to find an effect of homophony in Experiments VII and VIII depended on their use of stimulus lists in which only "different" pairs could differ phonemically (and hence any effect of phonemic information on "same" responses would be missed). Experiment VI, unlike these other experiments, used side-by-side presentation of word pairs, with smaller letters, which led to much longer response times than in the other studies. Under such conditions, phonemic processing might well begin to contribute to the letter-identity task. Indeed, we could most likely ensure that phonemic differences would affect this task by presenting members of each word pair successively rather than simultaneously, thereby forcing subjects to rely on short-term storage mechanisms, which are known to be strongly affected by phonemic information from visual presentations (Sperling, 1963; Conrad, 1964). Such short-term storage may even play a small part in Experiment VI.

This study was designed to reduce the likelihood that subjects would need to rely as heavily on memory coding, and to permit more rapid comparison of stimuli, to determine whether "same" decisions about letter-identity would be influenced by phonemic information when response times were commensurate with those in Baron's experiment.

METHOD

Subjects. 6 experienced subjects, all of whom were familiar with the apparatus and task, performed in this experiment in individual half-hour sessions.

Apparatus and Procedure. The same apparatus and procedure were used as in Experiment VI; however, the control program was modified just as in Experiments VII and VIII to present the stimulus pairs with one word atop the other. Each subject made 4 passes through the list of 112 stimulus pairs, with a brief rest period between passes for data retrieval. Rest periods could also be initiated during a session by holding down the response key after responding to a pair.

RESULTS

Table VII shows the results in terms of mean reaction times across the word pairs. There was no reliable difference between the times to respond to 'different' pairs that rhymed and the times to respond to those that did not rhyme ($t=1.06$, $df=13$); there was also no reliable difference between response times for rhyming and non-rhyming "same" pairs ($t=.322$, $df=13$). This latter result is quite different from that of Experiment VI.

DISCUSSION

Unlike Experiment VI, this study did not find a significant effect of phonemic information on "same" judgements of the letter-identities in word pairs. The crucial difference between this experiment and Experiment VI is that the times to respond in this study are far shorter than in the other, and in fact are of the same order as those in Baron's experiment, thanks to the vertical stimulus array used here, which permits easy comparison between corresponding letter positions for the two stimuli in each pair. As a result, subjects do not tend to incorporate phonemic information in their decisions in this experiment, most likely because it is not available by the time they are ready to respond on the basis of letter-identity. Once again, then, we find that if speed is at a premium and letter-by-letter comparisons between words can be made easily, subjects do not utilize phonemic information in their decisions about letter-identity.

The experiments just described indicate that subjects cannot ignore letter-identity information when making phonemic comparisons, but that they can ignore phonemic information when making letter-identity comparisons, even when the use of that information seems a priori very likely, as in Experiment VIII. This makes it likely that subjects are not merely ignoring phonemic information after processing it during the letter-identity task, but that in fact letter-identity information is completely available for decisions before phonemic information in these experiments (excepting Experiment VI).

The fact that subjects cannot attenuate letter-identity information adequately during the phonemic task sets limits to the sort of view of word processing proposed by Gibson (1971), for example. Subjects do not have unlimited freedom to attenuate all information but that required by the task at hand, when processing words. Even when processing for phonemic representations, they are unable to ignore letter-identity information.

CHAPTER FOUR

Transfer of Practice at Information Extraction

The experiments in the previous section looked at the effects of additional information upon tasks for which another type of information was designated as crucial. It was found that letter-identity and visual feature information influenced rhyme comparison tasks, but the converse was not usually true. To eliminate the possibility that phonemic information, though it did not influence visual feature and letter-identity tasks, was nonetheless extracted but ignored or suppressed, the experiments in this section were performed. They examine transfer from either rhyming or letter-identity practice to rhyming performance (Experiment X) and to letter-identity performance (Experiment XII). If phonemic information becomes available during processing for the letter-identity task, the ability to extract this information should improve with practice even though it is ignored at the time of decision, and this improvement should be equivalent to that produced by an equal amount of practice when the phonemic information cannot be ignored. The analogous argument holds for letter-identity and visual information.

The rationale for the transfer experiments which follow is that practice on a task requiring a given processing stage entails practice for only those stages required for the task. Hence any task to which there is transfer depends on one or more of the practiced processing stages in the original task. This depends on two assumptions:

I) with speed and accuracy instructions, subjects do not include any unnecessary stages in processing, and

II) the processing in a given stage is the same when the stage is part of one task as when it is part of another.

If there is no transfer from one task to another, we are not justified in concluding that no processes are common to both tasks. It may be that there are common processes, but they are not susceptible to the effect of practice, being practiced to an asymptotic level already, or requiring more practice for a noticable effect than given in the experimental situation.

When two tasks are compared, one of which depends on a certain number of processes, and the other upon all these processes plus an additional process, certain predictions can be made about the effects of practice on the two tasks. Practice on the task requiring all stages should transfer to the task depending on all but one of the stages. Moreover, this transfer should be no different from that produced by an equivalent amount of practice on the latter task itself. This is because all the processes necessary for the task which utilizes fewer processes will receive practice during performance of the task requiring these processes as well as additional processes. However, transfer from the task requiring fewer processes to the task requiring more should be less than that produced by an equivalent amount of practice on the latter task, because an additional process is required in the latter task which does not receive practice during the task requiring fewer processes.

A crucial methodological point must be discussed before experiment I is described, in order that the rationale for the choice of stimuli and conditions will be better understood. Since we are dealing with word comparison, we must consider the possibility that practice will improve the comparison of information as well as its extraction. However, our focus of interest is on differential improvements in extraction, so we must be sure that comparison processes are not producing differential transfer.

We must therefore give subjects prior experience with the general task they will later be tested on, in order that decision and response processes will be well practiced, but more important, we should try to give subjects experience on the specific comparisons on which they will later be tested, in case there is any effect of the specific comparison on the improvement of the comparison stage. For example, subjects who will be tested on comparing the letters in ROLL and ROLE could benefit more from practice comparing BALE and BALL, which differ in the same letters at the same position, than they could from comparing CENT and SENT, for which different letters in a different position are crucial.

The difficulty is that we must practice the comparison stage without also practicing the extraction of information from the specific stimuli which will later be tested. This is not too hard when the later test will be phonemic, because it is possible to give subjects practice with homophones of the words on which they will be later tested. Thus, subjects who will be tested on the phonemic comparison between FARE and HARE can be given PRETRAINING on the phonemic comparison between

FAIR and HAIR. Both pairs of words have the same phonemic representation, but they are physically (visually) different, and have different letters; practice at comparing FAIR and HAIR for rhyme should therefore give subjects practice at the phonemic comparison which is relevant to the subsequent test of FARE and HARE, but the specific practice at extracting phonemic information from FAIR, for example, should be largely irrelevant to extracting phonemic information from FARE, except insofar as there is any general effect of practice at phonemic extraction.

When we come to consider the ways in which subjects could be given specific pretraining for the letter-identity task, a tempting alternative presents itself. That is, we could use stimuli which are physically transformed from the stimuli which will be tested. Intraletter transformations could include the use of lower case type, say, for pretraining, and upper case type for testing, or some physical deformation such as changing the width of letter relative to their height, and so forth. Other geometric transformations could include letter inversion, mirror image reversal, and rotation (Kolers, 1966), which change either the interletter relationships, the relationship between word and context, or both.

Such transformations were not used even though they would have provided useful pretraining for the phonemic task too. A few tests with such transformations suggested that subjects would devote their attention to overcoming the transformations and then treating the stimuli in a "normalized form". There could be several undesirable consequences to this. Subjects might get practice at reversing the transformation rather than at the comparison of relevant information; they might also be so proficient at normalization of transformed stimuli when they come to the experiment that practice with transformed stimuli would be equivalent to practice with the test stimuli themselves. For these reasons, the use of physical transformations of the test stimuli was rejected for pretraining.

However, in Experiment XII, general practice at the letter-identity task is given, using stimuli which are related to the test stimuli homophonically but not physically, just as in this experiment. There is no particular reason to use homophonically related pretraining lists, other than that they were conveniently available, and are related to the test lists in the same fashion as the lists in this experiment. In fact, any pretraining list would give the subjects adequate practice at the general task. The absence of stimulus-specific pretraining of the letter-identity comparison task that results from this procedure weighs the scales in favour of transfer from letter-identity practice, and against transfer from rhyme practice. This is because subjects who get letter-identity practice with the test stimuli receive letter-identity comparison practice which is specific to the test stimuli. Subjects who only get rhyme practice with the stimuli to be tested for letter-identity should not get any practice at the specific comparison of letter-identities and consequently may suffer at the letter-identity comparison task, not because of differential practice at letter-identity extraction, but because they have not had to compare specific letter-identities before the test. If no difference in transfer to letter-identity performance is found between rhyme practice and letter-identity practice, then it is a strong argument that letter-identity information is extracted during rhyme processing, and that the comparison of letter-identity codes is not the crucial factor in these experiments, but rather what is important is the generation of letter-identity codes.

EXPERIMENT X

If phonemic and letter-identity information were extracted concurrently, no matter what the task demands (Rubenstein et al, 1971), then any improvement in the ability to extract one type of information should result in a concommittant improvement in ability to extract the other type of information. Practice tends to improve the ability to extract information about many qualities of a word, including phonemic information about many qualities of a word, including phonemic information and letter-identity (Gibson, 1971). Therefore, we would expect that practice at extracting phonemic information should improve the extraction of letter-identity information as well, and vice versa.

If, however, only phonemic information were extracted during a rhyme comparison task, and only letter-identity information were extracted during a letter comparison task, we should expect that practice on one task with a given stimulus should not transfer to performance of the other.

And if, as Experiments I and II suggest, phonemic information is not processed during a letter-identity task, but letter-identity information is processed or readily available during a phonemic task like rhyme comparison, practice on a task involving phonemic comparison should transfer to a task requiring evaluation of letter-identity for the same stimuli, but there should be little or no transfer from practice on letter-identity evaluation tasks to performance on a phonemic evaluation task. Experiment IX was performed to test the hypothesis that practice at letter-identity evaluation with a given stimulus would not transfer to phonemic evaluation of that stimulus as well as practice at phonemic evaluation itself.

METHOD

Subjects. 12 subjects have been run in this experiment (as a result of computer malfunction, data from 2 other subjects was lost, and the data from a third subject was rejected because of high variance, many errors, and report of unusual associative strategies not related to the task demands at all). The subjects compared pairs of 4 letter words for rhyme or for identity of the 3 terminal letters as in Experiments I and II.

Apparatus and Procedure. The same apparatus was used as in Experiments I and II. The control program was modified so that after subjects had seen all the stimulus pairs in a list, they pressed a teletype key which resulted in randomization of the order of presentation of the stimulus list again. Performance on the rhyme task for 10 consecutive exposures to the same 16-pair list of words (presented in different orders in each exposure) was compared after 10 training exposures to the same list during which either the rhyme task was performed or the letter-identity comparison task. Thus there were two conditions, the <u>rhyme-rhyme</u> condition and the <u>letter-rhyme</u> condition.

To ensure familiarity with the test task for both conditions, subjects were first given 10 pretraining exposures to a 16-pair list that was phonemically identical to the test list (it was constructed of homophones of the words in the test list): Table VIII shows a pretraining list of 16 words pairs and the homophonically identical list of 16 pairs used either for letter-identity training or for rhyme training, then tested on the rhyme comparison task. Two different pairs of homophonic lists were used; each subject saw one pair of lists for the letter-rhyme condition and the other pair of lists for the rhyme-rhyme condition. When all 12 subjects had been run, the order of the two conditions and the two pairs of lists was counterbalanced between subjects.

One experimental session consisted of the pretraining, training and test phases of an experimental condition, and took between 20 minutes and one half hour to perform. Between each phase of a session, the subject rested for a few minutes while data was collected and stimulus tapes were loaded into the computer's memory bank.

RESULTS

Mean reaction times for all responses are reported here. Because differences due to practice could be quickly eradicated by practice within the test list itself, data was grouped into two 5-repetition blocks of 80 trials. Table VIIIa shows that the rhyme task was performed more rapidly after previous rhyme practice than after previous letter-identity practice with the same stimulus list ($p < .05$, $t = 2.08$, $df = 8$) in the first 80 trials. There is a difference in the opposite direction for the last 80 trials, which however fails to reach significance ($p > .10$, $t = .53$, $df = 8$).

DISCUSSION

Since subjects had 160 practice trials on a rhyme task with phonemically identical stimuli during the pretraining phase for both the letter-rhyme and rhyme-rhyme conditions, the difference in performance at the time of the test phase is not attributable to total unfamiliarity with the rhyme task for the letter-rhyme condition: subjects had extensive practice at comparing the actual phonemes that were eventually tested in both conditions. Moreover, subjects had equal amounts of visual experience with the test stimuli in the two conditions, and, because letter-identity information was perfectly correlated with rhyme information in the practice phase, subjects had as much practice at assigning a particular physical response to a given stimulus in the letter-identity condition as in the rhyme condition during the training phase.

The differential effects of practice during the training phase can therefore be best traced to the availability of phonemic information from the specific visual stimuli used as a function of practice or lack of practice at extracting these phonemes. Practice at extraction of letter-identity information apparently does not give practice at the extraction of phonemic information - at least not to the same extent as when the subject must base his response on phonemic information.

EXPERIMENT XI

In Experiment X, subjects received training in two tasks before they were tested for transfer to a rhyme task. The first (pretraining) task was designed to give subjects practice at comparing the phonemic representations on which they would later be tested, without giving them practice at extracting such representations from the specific stimuli on which they would be tested. This was done by using lists which consisted of homophones of the stimuli used in the later test, which were spelled differently. Thus, if FARE HARE appeared in the test list as a stimulus pair, then FAIR HAIR appeared in the pretraining list.

The use of such lists was intended to ensure that subjects had sufficient practice at comparing the phonemic representations on which they would be tested so that any effects of subsequent practice could be attributed to improvement in the processes of analysis, feature extraction, etc., used to form the phonemic representations, rather than to the process of comparing such representations from two words. When such pretraining was completed, subjects were given new lists, and either compared the new pairs of words for rhyme or for letter-identity. Finally, their performance on the rhyme task for these new pairs was measured, and it was found that the pairs which had received prior rhyme training were responded to more rapidly than those which had received previous letter-identity training. It was argued that the rhyme training with those pairs improved the subjects' ability to extract or form phonemic information from the pairs more than the letter-identity training did.

However, the rhyme training condition differed from the letter-identity training not only because subjects were required to extract phonemic information only in the former case, but also because they received additional practice at comparison of this phonemic information from the pairs beyond the pretraining phase of the experiment. Therefore it could be argued that it was this additional practice at phonemic comparison which produced differential transfer, rather than practice at extraction of phonemic information. In other words, it could be argued that in spite of considerable practice at phonemic comparison with homophonic lists, the phonemic comparison processes were still susceptible to practice effects during the training phase of Experiment X, and that therefore the differential transfer effect was produced in the phonemic comparison stage.

The present experiment was designed to measure the effects of additional phonemic comparison practice in a situation similar to Experiment X, and demonstrate that the improvement in rhyme performance after rhyme practice was not due to differential amounts of practice at phonemic comparison. To do this, subjects were given pretraining on the rhyme task with one list of stimulus pairs; then they were given either rhyme or letter-identity practice with a new list of word pairs which were homophonically identical to the original list. Thus far, the design is identical to that of Experiment X; but now, subjects were tested for transfer back to the original list on the rhyme task. The middle (training) phase consisted of visually novel stimuli which were phonemically identical to the pretraining and test stimuli, but differed visually from both. Hence th iddle training phase gave those subjects who performed the rhyme task during this phase additional practice at comparison of the phonemic information which they had practiced and on which they would be tested.

If differential transfer in Experiment X is due to differential phonemic comparison practice, then subjects in this experiment who receive phonemic comparison practice with visually novel stimuli should perform the rhyme test better than those who receive letter-identity practice, because the former get more phonemic comparison practice with the same phonemic representations than do the latter. But if differential transfer in Experiment X is due to differential practice at phonemic extraction, then there should be no difference in transfer from the different training tasks to the test rhyme task, because both training conditions require extraction of information from different visual stimuli than those tested later.

METHOD

Subjects. 8 experienced subjects were paid to perform a single half-hour experimental session.

Apparatus and Procedure. The same stimulus lists and control program were used as for Experiment X. However, a different order of presentation of lists was used. There were two presentation conditions, the rhyme condition, and the letter-identity condition. Subjects were given 10 exposures to each of the pairs in a 16-item list, and required to decide whether the pairs rhymed or not. After this rhyme pretraining, they were given 10 exposures to a 16-item list of word pairs which were spelled differently than those in the first list, but were homophonically identical. In the rhyme condition, subjects decided whether these new pairs rhymed, while in the letter-identity condition, subjects decided whether or not the new pairs had identical terminal letter groups. Then subjects were given 10 more exposures to the old list; again they decided whether the word pairs rhymed. Consequently, subjects in the rhyme condition had twice as much opportunity to practice the phonemic comparison on which they were later tested as did subjects in the letter-identity condition. On the other hand, both conditions yielded equal practice at extraction of phonemic information from the specific visual stimuli which were later to be tested.

As in Experiment X, there were two sets of lists; each subject performed the rhyme condition using one set of homophonically related lists and the letter-identity condition using the other set of lists. 4 of the subjects performed the rhyme condition first, then the letter-identity condition, with one set of lists for the rhyme condition performed by 2 of these subjects, while the other two subjects performed the rhyme condition with the other set of lists. The other 4 subjects performed the letter-identity condition first, with appropriate balancing of sets of lists.

RESULTS

Mean reaction times are reported for the transfer test; as in Experiment X, data was grouped into two 5-repetition blocks of 80 trials each. The mean response time for all 8 subjects for the first 80 trials in the rhyme condition was 837 ms., while for the first 80 trials in the letter-identity condition, the mean response time was 819 ms.; these times do not differ significantly ($t=.336$, $df=7$, $p>.20$). The times for the last 80 trials, and the error rates for either the first or the last 80 trials also do not differ significantly.

DISCUSSION

The failure to find differential transfer to a rhyme task after rhyme practice as opposed to letter-identity practice indicates that in this experiment and in Experiment X, the phonemic pretraining phase gave sufficient practice at comparison of the relevant phonemic representations that further differential phonemic comparison practice did not improve the ability to compare phonemic representations. This in turn strengthens the argument that the differential transfer effect in Experiment X was due to differential practice of phonemic extraction processes.

EXPERIMENT XII

Experiment XII was performed to determine whether practice at the extraction of phonemic information helps extraction of letter-identity information from the same stimulus as much as does practice at letter-identity extractions itself.

METHOD

12 subjects compared pairs of 4 letter words similar to those described in Experiment X, except that they were given pretraining in the letter-identity task, then given training with a homophonic list on the letter-identity task, then tested on their ability to perform the letter-identity task (the letter-letter condition) or

given practice on this novel list for the rhyme task, and then tested on the letter-identity task (the rhyme-letter condition). As for Experiment IX, when all 12 subjects were run, order of performance of the two experimental conditions and the two pairs of lists was counterbalanced between subjects.

RESULTS

As Table IX shows, the letter-identity task was performed no faster after letter-identity training in the letter-letter conditions than after rhyme training in the rhyme-letter condition; in fact, there was a slight but unreliable trend in the opposite direction ($p > .05$, $t = .787$, $df = 10$) for the first 80 trials (test), and for the last 80 test trials ($p > .05$, $t = .72$, $df = 10$).

DISCUSSION

Unlike Experiment X, pretraining in this experiment was merely of a general nature, rather than specific to the information to be used in the test phase of the experiment. Thus in the letter-letter condition, subjects received more experience with the specific letter-identity comparisons than in the rhyme-letter condition (if indeed subjects in this condition received any experience with letter-identity comparison at all, it was due to their processing strategy, rather than to task demands). This should optimize the likelihood of finding more transfer from letter-identity training than from rhyme training. Nonetheless, not only is no such difference found, but in fact there is a trend in the opposite direction.

Therefore, it is concluded that practice at extraction of phonemic information in the rhyme task gives the subject practice as well at the extraction of letter-identity information, as one might extrapolate from the results of Experiments I and II. It could be argued that subjects do not perform differently in the two conditions of Experiment X because they ignored the instructions and only attended to letter-identity information and visual features. This was not the case, for subjects when questioned reported using the requested strategies. Moreover, in the rhyme tasks some subjects were unaware of spelling of the word pairs used when asked after a block of 160 trials, during which each word occurred as a member of a stimulus pair 40 times. In addition, there is clearly an effect of differential practice in Experiment X, indicating that subjects were following instructions to perform differentially in that experiment; there is no reason why they would not follow the same instructions in this experiment. Finally, all subjects but two were unaware until after the experiment that there was any correlation between spelling and rhyme in the experiment. This does not mean that subjects did not utilize the letter-identity and visual feature information during the rhyme task; however, it is unlikely that they ignored phonemic information, especially when it is considered that most had been subjects in previous experiments in which phonemic information could not be ignored.

It also might be argued that there is less transfer from letter-identity practice to rhyme performance than from rhyme practice because the subject need only attend to some of the letters in the letter-identity task, while he must attend to all of the letters in the rhyme task. Because from trial to trial, subjects did not know which were the crucial letters to expect, hence, they had to process all letters. It is, of course, conceivable that subjects learned quickly to ignore certain letters contingent on the occurrence of other letters.

To avoid some of these criticisms, the following experiment was performed.

EXPERIMENT XIII

In Experiments X, XI, and XII, subjects were not forced by the stimuli to adopt the letter-identity or rhyme strategy, since the responses to each stimulus pair were the same for both strategies. The stimuli, which were words printed in capital letters presented side-by-side, might have encouraged the use of visual feature-matching to the exclusion of letter-identity or rhyme information (Posner et al, 1969), or alternatively could have forced reliance on memory mechanisms. As well, the rhyme task, because it demands attention to most or all of the letters in a word, may provide more experience with relevant letters than does the letter-identity task, which could involve a comparison of letters which terminates when mismatch occurs, and therefore on 'different' trials need not involve examination of all letters in both words to be compared.

These factors combined might produce the pattern of results in Experiments X, XI, and XII: more transfer from rhyme practice than from letter-identity practice on the rhyme transfer test because of more experience with the relevant letters, and no difference in transfer to the letter-identity test, because of the use of a feature matching strategy which reduced the effects of practice. Subjects did not report that this was the way in which they performed the tasks, but to eliminate the possibility (and to render the stimuli more like those used in the other experiments of this thesis), Experiments X, and XII were repeated, using stimulus sets in which there were some pairs which terminated in the same letters but did not rhyme, and some pairs which terminated in different letters but rhymed, unlike the pairs in Experiments X and XII. To render feature-matching relatively ineffective, and to lessen the need for subjects to rely on memory mechanisms for the letter-identity task especially, the words in a pair were presented one above the other, with the upper word in capitals and the lower word in lower case letters.

Finally, to force the subjects to attend to all letter positions for both letter-identity and rhyme tasks, the letter-identity task was altered to that used in Experiments VII and VIII, namely to decide if the two words in a pair were spelled identically in <u>all</u> positions, rather than only in the last 3 letters as in Experiments X and XII.

METHOD

<u>Subjects</u>. 8 subjects served in a replication of Experiment X; another 8 served in a replication of Experiment XII.

<u>Apparatus and Procedure</u>. There were several changes in the procedure and in the stimulus sets. Rather than 10 repetitions of a 16-pair list, there were 3 repetitions of a 20-pair list. The display was changed from the side-by-side mode using capital letters to the vertical mode of Experiments VII and VIII, in which the top word in each pair is shown in capital letters while the bottom word is shown in lower case letters. There were differences in the pretraining lists and their uses as well.

Letter-identity pretraining used the same list for all subjects, and was used before both rhyme training and letter-identity training for each subject. The pretraining list was formed from pairs drawn from the set of words PARE, PEAR, FARE, and FEAR, so that there were two each of pairs with the same spelling (e.g.

PARE pare), and two each of pairs with different spelling, one pair in each possible order (e.g. PARE pear, PEAR pare). The letter-identity task required that subjects respond "same" to only those pairs in which both words had identical letters in all corresponding positions, such as PARE pare, and "different" to all other pairs such as FARE pare, etc.

As in Experiment X, rhyme pretraining lists were homophonically related to the subsequent list used for training and transfer; however some of the words in the pretraining lists were nonsense words. Thus corresponding to the training list made from the words FORE, FOUR, SORE, and SOUR was a pretraining list made from FOAR, FORR, SOAR, and SOWR. Subjects were instructed to pronounce these 'words' so that FOAR and FORR corresponded to FORE and FOUR, SOAR to SORE, and SOWR to SOUR. Similarily, a pretraining list was constructed from the 'words' ROES, ROZE, LOES, and LEWS, which corresponded to the training list constructed from ROWS, ROSE, LOWS, and LOSE respectively.

For clarification of the list structures, consider Table X, which shows pretraining and training lists. Note that for the letter-identity task, there are 8 "same" and 12 "different" stimuli, while for the rhyme task, 6 of the pairs which are spelled differently nevertheless rhyme, so there are 14 "same" stimuli including the 8 stimuli which are also given "same" responses in the letter-identity task, and 6 "different" stimuli. Aside from the different list structures and the modified letter-identity task, the procedure was identical to that of Experiments X and XII.

RESULTS and DISCUSSION

Table XI shows that the results of this experiment parallel those of Experiments X and XII. These results encompass only the 8 pairs which are spelled identically and the 6 pairs which do not rhyme and are spelled differently. These pairs require the same response in both the letter-identity task and the rhyme task, while the remaining pairs which were excluded from analysis require "same" responses in the letter-identity task but "different" responses in the rhyme task.

Because of the smaller number of observations this permitted, data was not resolved into early and late blocks as for the previous experiments. It was not felt that this would attenuate the pattern of results sufficiently to cause concern.

As in Experiment X the rhyme task was performed more rapidly when subjects had previously had rhyme training with the stimuli than when they had previously had letter-identity training ($p > .05$, $t = 2.32$, $df = 7$). And as in Experiment XII, the letter-identity task was performed no more rapidly when subjects had previously had letter-identity training with the stimuli than when their training was for rhyme ($p < .05$, $t = .53$, $df = 7$).

It might be argued that there will be low transfer from letter-identity training to the rhyme test because subjects must change their responses to some stimuli when they go from the training phase to the test phase. This might lead to a reluctance to rely on learned information during the test phase because some of it is unreliable. But this when extended would also predict that low transfer would occur from rhyme training to a letter-identity test, and this does not occur - at least, this transfer is as good as from letter-identity training itself.

These results, then, confirm those of Experiments X, XI, and XII, which makes it unlikely that the differential transfer found in those experiments is artifactual.

The results of the experiments in this section can best be interpreted by assuming that letter-identity processing occurs during phonemic comparison tasks, but that phonemic processing occurs only partially, if at all, during letter-identity comparison tasks. Experiments in the previous section could be interpreted in this way as well, or by assuming that complete phonemic processing occurred during letter-identity comparison, but that the results of this phonemic processing were somehow attenuated or ignored. The latter explanation can now be rejected, since it is inconsistent with the results of this section.

CHAPTER FIVE

CONCLUSIONS

In this concluding section, several alternative models will be described to account for subjects' performance in the experiments with written word comparisons reported in this thesis.

The experiments were designed to examine the flexibility hypothesis. In an extreme form, this hypothesis would state that information processing models which are stable enough to be flow-charted are too rigid to describe the fluid, changing strategies of word processing. A more moderate statement of the hypothesis is that, though a model which can be flow-charted may be suitable, subjects can ignore now this type of information, now that, according to the demands of the task at hand (Gibson, 1971). As applied to the research described in this thesis, the moderate form would predict that subjects could ignore letter-identity information when comparing words phonemically, to give one example. But this does not occur.

Instead, it is found that subjects cannot ignore letter-identity information during phonemic comparisons. Furthermore, it will be seen that several information processing models can describe the results of this series of experiments. This suggests that neither form of the flexibility hypothesis is valid for the tasks studied here. Yet the flexibility hypothesis has seemed fruitful in describing other, different types of word processing (Huey, 1908; Gibson, 1971).

When studying the ability to process words at the limits of perception, for example, we do well to take flexibility as the keynote, since in such situations it pays to be flexible, rather than adopt a rigid processing strategy which may fail to take advantage of all the potential information in the stimulus situation. But where speed and accuracy of response are at a premium, and the type of information which must be processed is clearly designated, flexibility may be less of an advantage than the use of a well-practiced processing strategy making use of information processing that is quick, easy, and reliable. The two aspects of word-processing should be thought of as complementary: Neither provides a total picture, while both must be considered.

In passing, it should be noted that the kinds of analyses which are to be described could be extended, in principle, to encompass visual feature extraction processes as well.

Performance on three different tasks must be accounted for. These tasks are all represented in Experiment I: they are the letter-identity task, in which subjects respond on the basis of letter-identity comparisons between words, the rhyme task in which subjects respond on the basis of phonemic comparisons, and the letter-identity + rhyme task in which subjects respond on the basis of both letter-identity and phonemic comparisons. Three different types of models will be proposed which might *a priori* account for letter-identity processing and phonemic processing. The same processing stages are postulated in each model; it is the interrelation between stages which differs from model to model.

The Stages. There are four stages of concern to us, as well as other necessary stages which are assumed to operate in the same way for all three models. Preceding the stages of concern, a visual feature extraction stage is presumed to operate on retinal input from visual word stimuli, analyzing this information into visual features. Then, there is a stage which operates on the output of the visual feature analysis stage to produce letter-identities as outputs; this stage can be called the letter-identity stage (LI). There is a stage which compares the outputs from the LI stage for two words; this stage can be called the letter-identity comparison stage (C(LI)). There is a stage analogous to LI which operates on the visual features, or the output of the letter-identity analysis (depending on which model is taken) to produce a phonemic representation as output (where the exact form of this representation is unspecified); call this stage the phonemic stage (P). The outputs of stage P for two words are compared by the phonemic comparison stage called C(P).

The outputs of the comparison stages C(LI) and C(P) feed decision and response mechanisms which, like the early visual feature analysis stage, are assumed to operate identically for all the experiments reported here, and which do not differ in their operation from model to model as well.

The Three Models. The first of the three models can be called the alternative processes model. In this model there are two alternative sets of processes which cannot operate simultaneously, one for letter-identity, the other for phonemic information. The letter-identity task is performed by stages LI and C(LI), as shown in figure Ia. The input comes to LI from the visual feature analyzers, as indicated by the left-most arrow; the output of this stage feeds C(LI), which in turn feeds the decision and response mechanisms, as indicated by the right-most arrow. The rhyme task is performed in analogous fashion, as figure Ib shows: stage P receives input from the visual feature analyzers, and feeds C(P), which feeds the decision and response mechanisms. The letter-identity + rhyme task is performed by processing one type of information, then delaying a decision (presumably this would involve some storage mechanism which will be attributed to the decision mechanisms) until the stimulus can be processed for the other type of information.

The second model is the parallel process model illustrated in figure II. In this model, visual feature analyzers provide input to both stage LI and stage P, which in turn feed C(LI) and C(P) respectively. Unlike the alternative processes model, this model assumes that the letter-identity and phonemic processing can occur concurrently. The letter-identity task is performed by ignoring the results of operating stages P and C(P) (even when one or the other type of information is not incorporated in the final decision, it may still be processed). The rhyme task is performed by ignoring the results of stages LI and C(LI), and the letter-identity + rhyme task is performed by utilizing both types of information. Because it is possible and likely that it takes different lengths of time to complete phonemic processing than to complete letter-identity processing, there is probably some provision, as well, for the storage of the output of one or the other extraction or comparison stages during the delay between completion of that stage and completion of the analogous stage processing the other type of information.

Illustrated in figure III is a successive stage model in which visual feature analyzers feed LI, which in turn feeds C(LI) and P; P then feeds C(P). Both the comparison stages C(LI) and C(P) then feed the decision and response mechanisms. The comparison stage C(LI) can presumably operate concurrently with stages P and C(P); however this model is designated a successive stage model because the stages of principle interest to us in these investigations are connected successively, rather than operating alternatively or concurrently.

According to this model, the letter-identity task is performed by ignoring stages P and C(P) and using stages LI and C(LI), the rhyme task is performed by utilizing stages LI, P, and C(P), while ignoring C(LI). The letter-identity + rhyme task is performed by utilizing all stages; as for the alternative processes model and the parallel process models, there is probably provision for storage of output from one or the other of the extraction or comparison stages, since it is likely that the letter-identity comparison stage completes processing before the phonemic comparison stage.

Having described three types of models which could accommodate the basic tasks used in the experiments reported in this thesis, it is now possible to evaluate how well each model accounts for the results obtained.

The Monitoring of Additional Information. It was found that to respond to letter-identity plus phonemic information from the same stimuli takes longer than to respond to letter-identity alone, but no longer than to respond to phonemic information alone. In fact, for pairs which differed for both letter-identity and phonemic information, it took less time to respond on the basis of letter-identity and phonemic information than to respond on the basis of phonemic information alone (but more time than to respond on the basis of letter-identity alone). These findings cannot be accounted for by the alternative processes model, since it would predict that, for some stimulus pairs (such as FOUR SOUR), the letter-identity + rhyme condition should have longer response times than the rhyme condition, which is not the case. The parallel processes model can accommodate these results with three additional assumptions. The first assumption is that letter-identity processing and comparison is completed as soon as or before phonemic processing is completed. Then, it would take no longer to respond to phonemic information and letter-identity information than to respond to phonemic information alone, and stimuli which rhyme and match for letter-identity such as FORE SORE would be responded to on the basis of rhyme plus letter-identity more slowly than on the basis of letter-identity alone.

The second assumption required by the parallel processes model to explain the effects of required additional processing is that the necessity of processing phonemically as well as for letter-identity slows the ability to extract or utilize letter-identity information, perhaps because of redistribution of a limited processing capacity. This would lead us to predict the increased time to respond to pairs of words which do not match for letter-identity in the letter-identity + rhyme task over the times to respond to the same pairs in the letter-identity task (note that a letter-identity mismatch is always sufficient for a "different" response in both the letter-identity task and the letter-identity + rhyme task). However, we would also predict that the capacity sharing should slow the ability to utilize phonemic information. Since this is not the case, we need a third assumption. It may be that letter-identity information must always be processed when phonological information is processed, so that capacity sharing is occurring, but phonemic information processing always shares capacity with letter-identity processing, even when the latter is not required by the experimental conditions. Thus, during performance of those tasks requiring phonemic information but not letter-identity, the subject would still be processing for letter-identity. Hence, as far as capacity sharing is concerned, there would be no difference between the rhyme task and the letter-identity + rhyme task.

The successive stage model can handle the results described above with the additional assumption that when a subject expects to process a stimulus for phonemic information, more capacity is required to prepare for this than is required to prepare for letter-identity processing alone. Such a model would predict that the ability to utilize letter-identity information would be slowed by the requirement of additional (conjoint) processing for rhyme, while the ability to utilize rhyme information would be unaffected by the requirement of additional letter-identity processing. An alternative assumption might be that subjects always do some phonemic processing in the letter-identity + rhyme task, even when letter-identity information is sufficient to permit a response (as for pairs like FORE SOUR). This would of course increase the time to process pairs which differ for letter-identity relative to the time in the letter-identity condition.

The Effect of Phonemic Information on a Letter-Identity Task. The speed of letter-identity judgements was not influenced by phonemic information (except when stimulus conditions favoured such long response times that the use of phonemic recoding would be an advantage). That is, it took no less time to decide that word pairs like FOUR SOUR had the same terminal letters (even though they did not rhyme) that to make the same decision for rhyming pairs like FORE SORE. In the former case, phonemic information would be more likely to suggest a "different" response than in the latter case, because there is an additional phonemic difference between words in the former case beyond that in the latter case. Similarily, pairs which rhyme (like FOUR SORE) were judged to differ in their terminal letters no more slowly than pairs like FORE SOUR, which do not rhyme.

All three models can accommodate this result. In the alternative processes model, phonemic information is not processed during the letter-identity task, and so can have no effect on performance of the task. If phonemic information is incompletely processed at the time of response, or ignored, then the parallel process model, too, can account for the lack of effect of phonemic information in the letter-identity task, except under display conditions which increase response time and may encourage more use of storage mechanisms. The successive stage model can also handle this result, because phonemic information need not be processed for the letter-identity task according to this model.

<u>The Effect of Letter-Identity Information on a Rhyme Task.</u> In contrast, it was discovered that letter-identity information influenced the time to make comparisons based on phonemic information. For example, it took longer to decide that pairs of words rhymed when their terminal letters differed as for the pair FOUR SORE than when their terminal letters did not differ, as in the pair FORE SORE. The alternative processes model can account for this result if we assume that on some trials subjects process for letter-identity as well as for rhyme, and that discrepancies between letter-identity information and phonemic information lead to confusion and increased latency. The parallel processes model can handle the result with the assumption that letter-identity information is processed, and that this letter-identity information at least occasionally leads to confusion and increased latency when it and phonemic information are discrepant. Since letter-identity information is processed before phonemic information in the successive stage model, if this information is also compared on some trials during the rhyme task, then (as for the other models) discrepancies between letter-identity and phonemic comparisons

may lead to confusion and increased latencies.

The Transfer of Practice. There are two findings in the studies of transfer of practice reported in this thesis. The first finding is that practice at extraction of phonemic information transfers to extraction of letter-identity just as well as does practice at letter-identity extraction itself, in terms of latency of response. The alternative process model cannot handle this result unless on some practice trials, subjects process for letter-identity as well, even though only phonemic information is required. This would result in some practice of stages LI and C(LI). The parallel processes model can cope with this finding as well, if it is assumed that subjects also process for letter-identity during the rhyme task. The successive stage model can account for the result readily, because practice at operation of the phonemic stage in this model necessarily involves practice at operation of the letter-identity stage.

The second finding is that practice at extraction of letter-identity does not transfer to the extraction of phonemic information as well as practice at extraction of phonemic information itself. This finding can be accounted for by the alternative processes model, since according to that model, phonemic extraction processes do not operate during the letter-identity task. The parallel processes model can also handle the result, with one (or both) of two additional assumptions; it may be that subjects do not process phonemic information during the letter-identity task, or it may be that though the two types of processing operate concurrently, that letter-identity information is completely extracted more rapidly that phonemic information and that completion of letter-identity processing 'aborts' phonemic processing. If the latter assumption holds, then phonemic extraction processes would get less practice during the letter-identity task than during the rhyme task. The successive stages model accounts for this result without additional assumptions, because according to the model, the letter-identity task does not involve the phonemic extraction and comparison stages (P and C(P)) required by the rhyme task. Consequently there should be low transfer from the letter-identity task to the rhyme task.

<u>The Choice of Models</u>. Of the three models, the alternative processes model can be rejected as an overall explanation of performance in the various tasks studied here, because of its failure to accommodate the results of experiments on monitoring one type of information as opposed to two types. The parallel process model requires more assumptions than the successive stages model to account for the effects reported here, and therefore the successive stages model seems preferrable on grounds of parsimony. Interestingly, both models require that letter-identity information becomes available before phonemic information. The difference is that this occurs (necessarily) as a feature of the suc-

cessive stages model resulting from its structure, while it is an additional assumption concerning parameter values in the parallel process model.

Whichever explanation is correct, three important limitations upon word processing are clear from the studies reported here. First, subjects do not utilize or process phonemic information in a number of tasks in which it might be helpful for them to do so. Second, subjects not only utilize visual features and letter-identity when helpful, but they cannot suppress it a phonemic task in which it would be helpful to do so. Third, phonemic processing uses letter processing mechanisms, as shown by the transfer experiments described.

Baron (1973) has argued against the view of word-processing as a highly flexible problem-solving task on similar grounds. Certainly, the view proposed by Gibson (1971) that subjects 'filter out' features of words irrelevant to task demands, and attend to what features help in the performance of a task, must be moderated: after a lifetime of reading, some classes of features must become more salient than others, when speed is at a premium.

TABLE I

Mean reaction times to pairs of words in Experiment I (N=16)

STIMULI	What is being compared		
	Letter Identity	Letter Identity + Rhyme	Rhyme
(Pairs used in the letter-identity and letter-identity + rhyme tasks)			
Look Same/Rhyme (e.g. BOAR SOAR)	896 ms	1267 ms	---
Look Different/Rhyme (e.g. BOAR CORE)	999 ms	1283 ms	---
(Pairs used in the rhyme and letter-identity + rhyme tasks)			
Look Same/Rhyme (e.g. BEAR PEAR)	---	1278 ms (ns)	1261 ms
Look Same/Don't Rhyme (e.g. BEAR FEAR)	---	1360 ms (ns)	1389 ms

"(ns)" between two adjacent numbers indicates that they do not differ significantly.

TABLE II

Mean reaction times (across 8 subjects) for stimuli used in Experiment II, when one member of each stimulus pair was in lower case print.

STIMULI	What is being compared		
	Letter Idntity	Letter Identity + Rhyme	Rhyme
(Pairs used in the letter-identity and letter-identity + rhyme tasks)			
Look Same/Rhyme (e.g. BOAR soar)	1196 ms	1564 ms	---
Look Different/Rhyme (e.g. BOAR core)	1288 ms	1580 ms	---
(Pairs used in the rhyme and letter-identity + rhyme tasks)			
Look Same/Rhyme (e.g. BEAR pear)	---	1626 ms (ns)	1459 ms
Look Same/Don't Rhyme (e.g. BEAR fear)	---	1687 ms (ns)	1692 ms

"(ns)" between two adjacent numbers indicates that they do not differ significantly.

TABLE III

Reaction times to pairs of words being compared for terminal letters identity, rhyme, or both, in Experiment III (Mean of 16 subjects).

STIMULI	What is being Compared. Letter-Identity	Letter-Identity + Rhyme	Rhyme
Look Same/Rhyme (LS-SS, e.g. FORE sore)	1147 ms.	1394 ms. (ns)	1348 ms.
Look Same/Don't Rhyme (LS-SD, e.g. FOUR sour)	1235 ms. (nc)	1788 ms. (ns)	1747 ms.
Look Different/Rhyme (LD-SS, e.g. FOUR sore)	1177ms.	1435 ms. (nc)	1658 ms.
Look Different/Don't Rhyme (LD-SD, e.g. FORE sour)	1172 ms.	1361 ms.	1717 ms.

("(ns)" between two adjacent numbers indicates they do not differ significantly; "(nc)" between two numbers indicates that they were not compared because they required different responses to the same stimuli.)

TABLE IIIa

The stimulus pairs that were used in Experiments III, V, and VI.

RHYME (LS-SS)	DON'T RHYME (LS-SD)	RHYME (LD-SS)	DON'T RHYME (LD-SD)
FORE SORE	FOUR SOUR	FOUR SORE	FORE SOUR
BALM CALM	BOMB COMB	BOMB CALM	BALM COMB
WARE DARE	WEAR DEAR	WEAR DARE	WARE DEAR
PAIR HAIR	PEAR HEAR	PEAR HAIR	PAIR HEAR
SO NO	SEW NEW	SEW NO	SO NEW
TOE HOE	TOW HOW	TOW HOE	TOE HOW
ROLE DOLE	ROLL DOLL	ROLL DOLE	ROLE DOLL
BOLE HOLE	BOWL HOWL	BOWL HOLE	BOLE HOWL
BRAKE SNAKE	BREAK SNEAK	BREAK SNAKE	BRAKE SNEAK
HUE SUE	HEW SEW	HEW SUE	HUE SEW
RUFF BUFF	ROUGH BOUGH	ROUGH BUFF	RUFF BOUGH
ROWS LOWS	ROSE LOSE	ROSE LOWS	ROWS LOSE
DUN BUN	DONE BONE	DONE BUN	BUN BONE
NUN SUN	NON SON	NUN SON	NON SUN

TABLE IV

Mean correct reaction times to those pairs of words used both in the correlated and the imperfectly correlated conditions in Experiment IV (means across 8 subjects).

	Comparison of terminal letters always correlated with rhyme	Comparison of terminal letters sometimes uncorrelated with rhyme
Pairs requiring "same" response (e.g. BARE dare)	910 ms	1083 ms
Pairs requiring "different" response (e.g. BARE deer)	980 ms	1206 ms

TABLE V

Reaction times to judge whether pairs of words had the same or different letters in Experiment VII. Each of the four conditions represents a mean of the times for 16 words, where the time for each word is the mean of 48 trials, 6 contributed by each of 8 subjects.

	HOMOPHONES		NON-HOMOPHONES
"Same" pairs	951 ms.		961 ms.
"Different" pairs	976 ms.	(ns)	974 ms.

TABLE VI

Reaction times to judge whether pairs of words had the same or different letters in Experiment VIII. Each of the four conditions represents a mean of the times for 16 words, where the time for each word is the mean of 64 trials, 8 contributed by each of the 8 subjects. The homophone pairs were presented in different blocks than the non-homophone pairs.

	HOMOPHONES		NON-HOMOPHONES
"Same" pairs	1080 ms.		1070 ms.
"Different" pairs	1159 ms.	(ns)	1154 ms.

TABLE VII

Reaction times to pairs of words being compared for terminal letter-identity when the words were presented one atop the other in Experiment IX. Each number represents the mean of 672 observations contributed by 6 subjects.

STIMULI	MEAN REACTION TIME
Look Same/Rhyme (LS-SS, e.g. FORE-SORE)	760 ms *
	(ns)
Look Same/Don't Rhyme (LS-SD, e.g. FOUR-SOUR)	766 ms *
Look Different/Rhyme (LD-SS, e.g. FOUR-SORE)	801 ms **
	(ns)
Look Different/Don't Rhyme (LD-SD, e.g. FORE-SOUR)	813 ms **

* These two figures do not differ reliably (t=.322, df=13).

** These two figures also do not differ reliably (t=1.05, df=13).

TABLE VIII

A sample pretraining list and its homophonic counterpart for training and testing in Experiments X, XI and XII. Subjects received 10 pretraining exposures to list A, then 10 training exposures to list B and finally 10 test exposures to list B.

PRETRAINING LIST A		TRAINING AND TEST LIST B
	RHYMING WORDS, SAME TERMINAL LETTERS	
FAIR HAIR		FARE HARE
HAIR FAIR		HARE FARE
MALE SALE		MAIL SAIL
SALE MALE		SAIL MAIL
DEER SEER		DEAR SEAR
SEER DEER		SEAR DEAR
FORE PORE		FOUR POUR
PORE FORE		POUR FOUR
	NON RHYMING WORDS WITH DIFFERENT TERMINAL LETTERS	
FAIR MALE		FARE MAIL
MALE FAIR		MAIL FARE
HAIR SALE		HARE SAIL
SALE HAIR		SAIL HARE
DEER FORE		DEAR FOUR
FORE DEER		FOUR DEAR
SEER PORE		SEAR POUR
PORE SEER		POUR SEAR

TABLE VIIIa.

Mean reaction times for 12 subjects to decide whether pairs of words rhymed after two different practice conditions with the same stimuli (in Experiment X).

	Rhyme Training	Letter-Identity Training
Rhyme Transfer Test, Trials 1 - 80	775 ms.	824 ms.
Trials 81 - 160	753 ms. (ns)	747 ms.

TABLE IX

Mean reaction times for 12 subjects to decide whether pairs of words had the same terminal 3 letters after two different practice conditions with the same stimuli (in Experiment XII).

	Rhyme Training		Letter-Identity Training
Letter-Identity Transfer Test, Trials 1 - 80	679 ms	(ns)	697 ms.
Trials 81 - 160	706 ms.	(ns)	716 ms.

TABLE X

Sample Pretraining lists and a pretraining and test list for Experiment XIII.

RHYME PRETRAINING LIST	LETTER-IDENTITY PRETRAINING LIST	TRAINING/TRANSFER LIST
	(Rhyme, spelled the same)	
FOAR foar	FARE fare	FORE fore
FOAR foar	FARE fare	FORE fore
FORR forr	PEAR pear	FOUR four
FORR forr	PEAR pear	FOUR four
SOAR soar	FARE fare	SORE sore
SOAR soar	FARE fare	SORE sore
SOWR sowr	FEAR fear	SOUR sour
SOWR sowr	FEAR fear	SOUR sour
	(Rhyme, spelled differently)	
FOAR forr	PARE pear	FORE four
FORR foar	PEAR pare	FOUR fore
FOAR soar	PARE fare	FORE sore
SOAR foar	FARE pare	SORE fore
FORR soar	PEAR fare	FOUR sore
SOAR forr	FARE pear	SORE four
	(Don't rhyme, spelled differently)	
SOWR foar	FEAR fare	SOUR fore
FOAR sowr	FARE fear	FORE sour
SOWR forr	PEAR pare	SOUR four
FORR sowr	PARE fear	FOUR sour
SOWR soar	FEAR pear	SOUR sore
SOAR sowr	PEAR fear	SORE sour

TABLE XI

Mean reaction times to pairs of words in Experiment XIII.

	Rhyme Training		Letter-Identity Training
Rhyme Transfer Test (8 subjects)	694 ms.		761 ms.
Letter-Identity Transfer Test (8 subjects)	650 ms.	(ns)	647 ms.

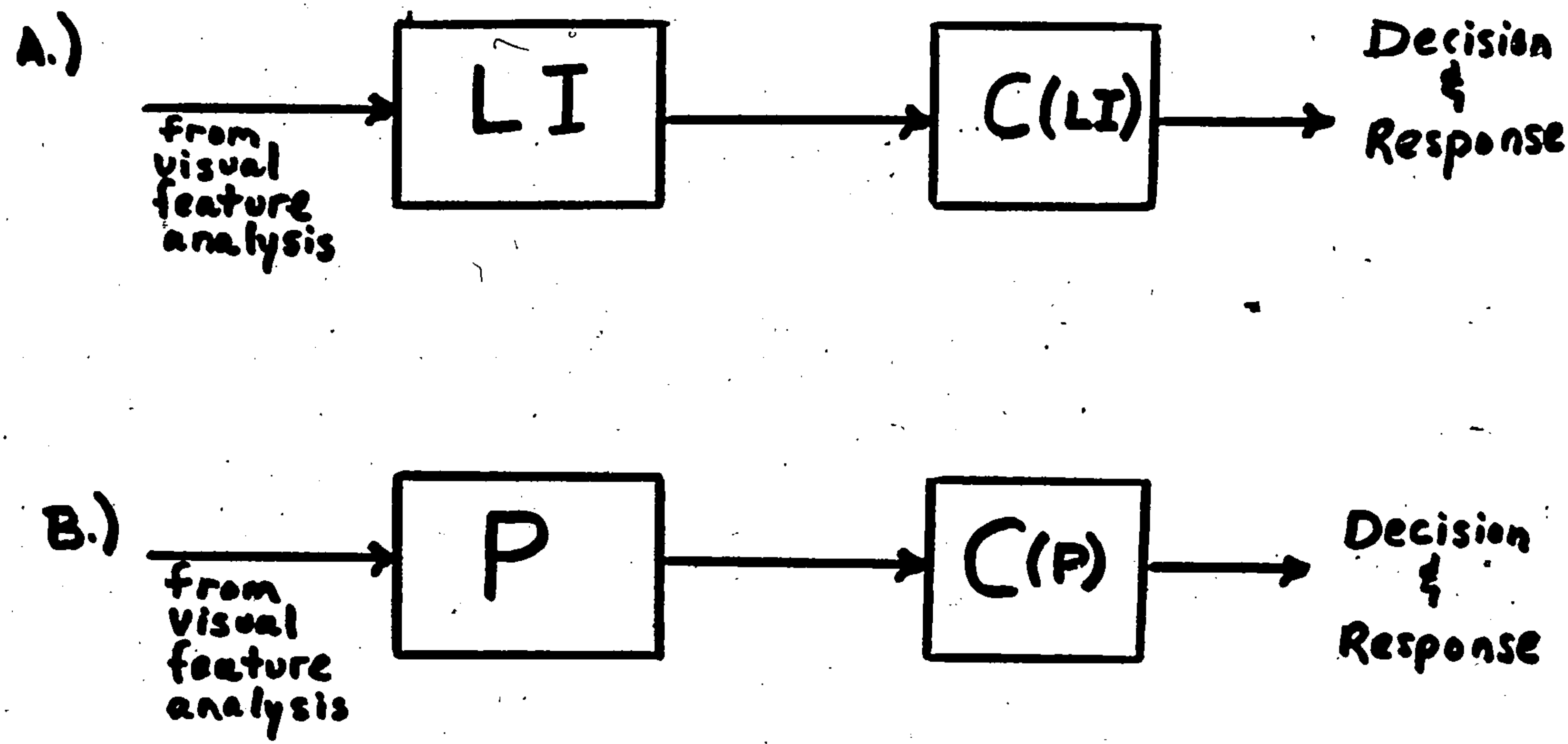

Figure I. The flow chart-of the alternative processes model
a.) for the letter identity task, and
b.) for the rhyme task.

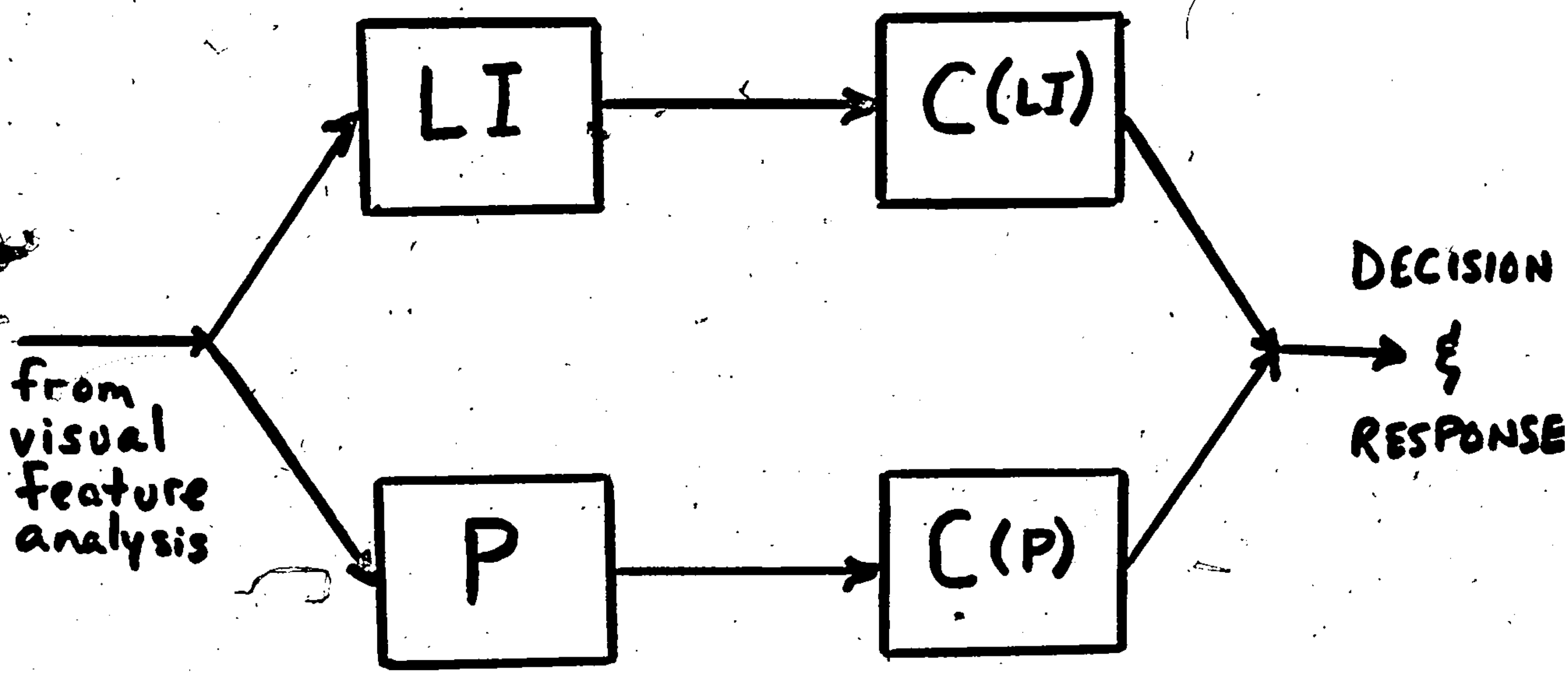

Figure II. The flow chart of the parallel processe model.

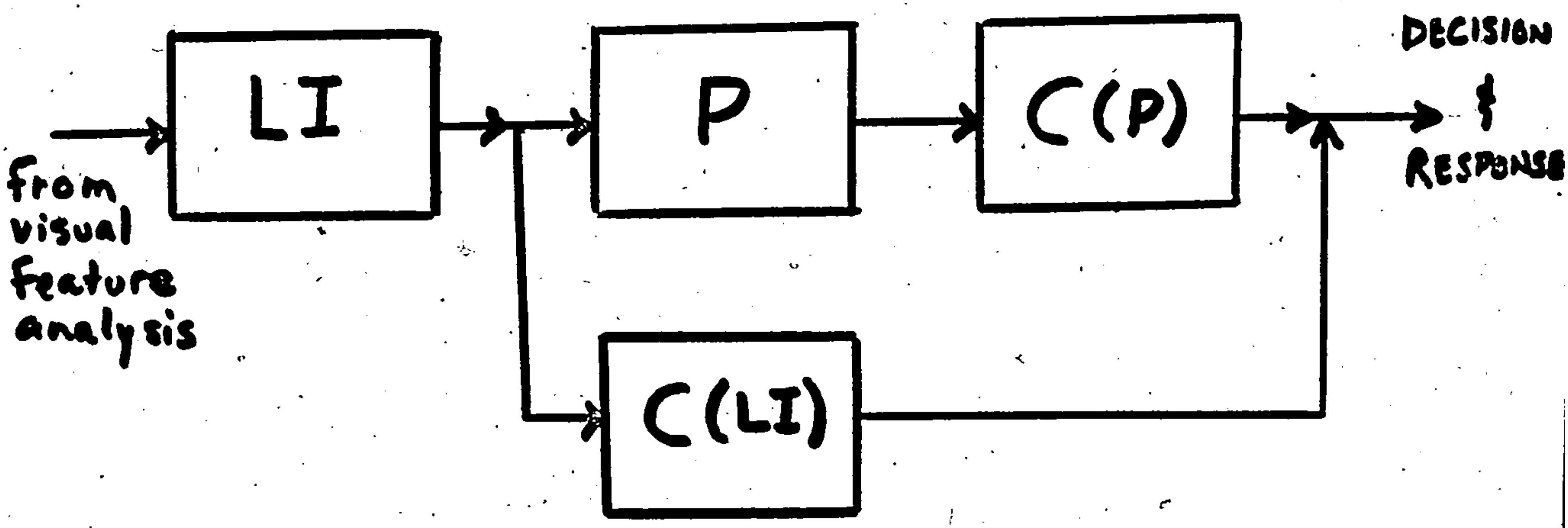

Figure III. The flow chart of the successive stage model .

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Appendix A: Reaction times for each subject for the experiments reported in this thesis, by stimulus condition.

In all cases, mean reaction times in milliseconds are what is reported.

Table A-I. Experiment I; stimuli used in letter-identity and letter-identity + rhyme conditions. Reaction times reproted in milliseconds.

Subject	Letter-identity Condition		Letter-identity + rhyme Condition	
	LS-SS pairs (e.g. BOAR-SOAR)	LD-SS pairs (e.g. BOAR-CORE)	LS-SS pairs	LD-SS pairs
1	735	776	836	919
2	848	983	1440	1216
3	924	1087	1141	1232
4	1162	1285	1630	1743
5	847	954	1182	1312
6	658	689	825	842
7	793	918	1221	1126
8	737	782	836	989
9	1026	1217	1481	1741
10	819	852	1281	1230
11	1321	1531	1444	1476
12	1085	1152	1688	1564
13	847	913	1650	1615
14	577	569	792	948
15	836	995	1290	1197
16	1121	1279	1536	1371
MEAN:	896	999	1267	1283

Table A-II. Experiment I; stimuli used in rhyme and letter-identity + rhyme conditions.

Subject	Rhyme Condition		Letter-identity + rhyme Conditon	
	LS-SS pairs (e.g. BEAR-PEAR)	LS-SD pairs (e.g. BEAR-DEAR)	LS-SS pairs	LS-SD pairs
1	940	999	860	946
2	1201	1500	1348	1430
3	1119	1523	1221	1329
4	1771	1695	1428	1691
5	1234	1456	1163	1274
6	863	887	905	924
7	1509	1743	1468	1493
8	850	982	884	1038
9	1396	1617	1557	1604
10	1209	1266	1278	1446
11	1564	1670	1581	1645
12	1539	1516	1670	1718
13	1073	1411	1517	1589
14	869	934	683	735
15	1346	1496	1296	1459
16	1689	1535	1588	1440
MEAN:	1261	1389	1278	1360

Table A-III. Experiment II; stimuli used in letter-identity and letter-identity + rhyme condition.

Subject	Letter-identity Condition		Letter-identity + rhyme Condition	
	LS-SS pairs	LD-SS pairs	LS-SS pairs	LD-SS pairs
1	1881	2221	2112	2013
2	1237	1338	1438	1608
3	1613	1565	2274	2298
4	1050	1158	1728	1675
5	755	788	756	849
6	1544	1637	2091	1902
7	871	942	1196	1449
8	618	657	759	846
MEAN:	1196	1288	1544	1580

Table A-IV. Experiment II; stimuli used in rhyme and letter-identity + rhyme conditions.

Subject	Rhyme Condition LS-SS pairs	Rhyme Condition LS-SD pairs	Letter-identity + rhyme Condition LS-SS pairs	Letter-identity + rhyme Condition LS-SD pairs
1	1915	2383	1966	2363
2	1486	1680	1571	1881
3	1531	2040	2679	2356
4	1935	2043	1829	1857
5	804	876	827	900
6	1920	2263	2129	2197
7	1229	1318	1196	1070
8	850	933	810	868
MEAN:	1459	1692	1626	1687

Table A-V. Experiment III; letter-identity task.

Subject	LS-SS pairs (e.g. FORE-sore)	LS-SD pairs (e.g. FOUR-sour)	LD-SS pairs (e.g. FOUR-sore)	LD-SD pairs (e.g. FORE sour)
1	905	861	972	954
2	541	538	553	592
3	555	566	600	575
4	1911	1974	1492	1503
5	1088	1220	1133	1190
6	1832	2027	1821	1851
7	528	564	584	585
8	1080	1197	1324	1259
9	977	1159	1236	1165
10	1650	2070	1810	1924
11	999	894	989	905
12	1503	1661	1498	1448
13	1339	1441	1339	1199
14	1024	1060	1174	1216
15	1066	1124	1108	1121
16	1353	1417	1207	1255
MEAN:	1147	1235	1177	1172

Table A-VI. Experiment III; rhyme task.

Subject	LS-SS pairs	LS-SD pairs	LD-SS pairs	LD-SD pairs
1	981	1446	1180	1153
2	641	719	676	720
3	768	921	895	955
4	1534	1890	2054	2338
5	1362	1552	1538	1612
6	1204	1717	1542	1568
7	780	936	879	902
8	1285	1672	1606	1763
9	1620	2354	1921	1889
10	1599	2703	2300	2651
11	1414	1631	1635	1687
12	1628	2138	1869	1872
13	2038	2202	2458	2246
14	1533	2103	2071	1381
15	1527	1862	1851	1788
16	1654	2100	2049	2442
MEAN:	1348	1747	1658	1717

Table A-VII. Experiment III; letter-identity + rhyme task.

Subject	LS-SS pairs	LS-SD pairs	LD-SS pairs	LD-SD pairs
1	1194	1742	1742	1181
2	594	611	600	607
3	654	743	687	690
4	1989	2149	1390	1555
5	1148	2059	1142	1202
6	1718	1891	1674	1618
7	613	699	662	641
8	1510	1717	2054	1896
9	1929	2310	1796	1638
10	2153	2904	2423	2129
11	1164	1470	1383	1177
12	1634	2207	1537	1506
13	1814	2197	2054	1896
14	1362	1713	1617	1764
15	1296	1717	1343	1416
16	1526	2480	1506	1422
MEAN:	1394	1788	1435	1361

Table A-VIII. Experiment IV; comparison of "congruent" and "noncongruent" stimuli.

Subject	Congruent Condition: LS-SS pairs (e.g. BARE-dare)	Congruent Condition: LD-SD pairs (e.g. BARE-deer)	Noncongruent Condition: LS-SS pairs	Noncongruent Condition: LD-SD pairs
1	1391	1464	1568	1631
2	1267	1352	1432	1519
3	618	660	870	917
4	945	1015	1125	1279
5	893	985	1200	1354
6	487	561	585	760
7	664	738	797	931
8	1017	1068	1083	1253
MEAN:	910	980	1083	1206

Table A-IX. Experiment VII; letter-identity task.

Subject	Homophones LS-SS pairs (e.g. FORE-fore)	LD-SS pairs (e.g. FORE-four)	Nonhomophones LS-SS pairs (e.g. SORE-sore)	LD-SD pairs (e.g. SORE-sour)
1	1181	1252	1172	1202
2	660	679	666	700
3	1313	1360	1328	1301
4	1528	1420	1542	1453
5	743	763	732	795
6	563	603	568	625
7	530	562	530	540
8	1098	1197	1121	1200
MEAN:	952	979	957	977

Interaction measure (derived by using performance on LS-SS pairs as a baseline for performance on LD-SS pairs for homophones, and on LD-SD pairs for nonhomophones. The measure is a t-test comparing the difference between the entry in column 1 and that in column 2 with the difference between the entry in column 3 and that in column 4): t=.582, df=15 (not significant)

Table A-X. Experiment VIII; letter-identity task

Subject	Homophones LS-SS pairs (e.g. FORE-fore)	LD-SS pairs (e.g. FORE-four)	Nonhomophones LS-SD pairs (e.g. SORE-sore)	LD-SD pairs (e.g. SORE-sour)
1	875	985	789	974
2	921	1000	967	1076
3	1259	1390	1031	1183
4	883	846	940	896
5	1189	1254	1164	1257
6	1533	1616	1683	1658
7	1089	1109	1049	1114
8	892	984	913	990
MEAN:	1080	1160	1055	1144

Interaction measure: t=.444, df=15 (not significant)

Comparison of homophone and nonhomophone "different" pair responses: t=.54, df=7 (not significant)

Table A-XI. Experiment X; transfer to rhyme task.

Subject	First 80 transfer trials Rhyme Training	Letter-Identity Training	Last 80 transfer trials Rhyme Training	Letter-Identity Training
1	453	559	469	546
2	866	938	832	778
3	529	587	559	552
4	509	574	470	536
5	620	770	649	701
6	618	750	579	641
7	1189	1075	1177	1074
8	1083	1235	1006	1060
9	944	893	874	832
10	887	780	710	693
11	909	906	953	806
12	778	809	783	789
MEAN:	775	823	755	750

Table A-XII. Experiment XI; transfer to rhyme task.

Subject	First 80 transfer trials: Rhyme Training	First 80 transfer trials: Letter-Identity Training	Last 80 transfer trials: Rhyme Training	Last 80 transfer trials: Letter-Identity Training
1	1106	1121	1001	1006
2	686	698	557	694
3	954	707	796	803
4	814	1040	715	815
5	762	912	765	865
6	851	777	785	720
7	640	501	632	531
8	881	792	821	742
MEAN:	837	819	759	772

Table A-XIII. Experiment XII; transfer to letter-identity task.

Subject	First 80 transfer trials: Rhyme Training	First 80 transfer trials: Letter-Identity Training	Last 80 transfer trials: Rhyme Training	Last 80 transfer trials: Letter-Identity Training
1	531	522	520	495
2	724	729	730	761
3	488	541	480	534
4	533	521	516	495
5	682	732	706	709
6	663	588	651	544
7	837	833	831	898
8	970	943	924	899
9	734	841	723	800
10	728	729	629	740
11	797	834	752	735
12	782	777	692	753
MEAN:	706	716	679	697

Table A-XIV. Experiment XIII; transfer to rhyme task and to letter-identity task.

Rhyme task

Subject	Rhyme Training	Letter-identity Training
1	502	515
2	734	894
3	508	543
4	492	543
5	657	726
6	597	706
7	1016	1101
8	999	1030
MEAN:	694	761

Letter-identity task

Subject	Rhyme Training	Letter-identity Training
9	722	672
10	549	570
11	930	871
12	840	873
13	523	565
14	473	495
15	482	460
16	667	670
MEAN:	650	647

Appendix B: Reaction times across stimuli, rather than across subjects, for those experiments in which such analysis was possible.

Reaction times are reported in milliseconds.

Table B-I. Experiment III; letter-identity task. The word-groups can be found in Table III a.

Word-group	LS-SS pairs	LS-SD pairs	LD-SS pairs	LD-SD pairs
1	1222	1196	1209	1248
2	1198	1228	1186	1108
3	1209	1289	1276	1272
4	1055	1248	1122	1221
5	911	1096	956	928
6	1207	1094	1087	1120
7	1136	1104	1193	1044
8	1126	1151	1128	1234
9	1256	1468	1429	1316
10	1137	1180	1267	1294
11	1007	1475	1061	1122
12	1326	1394	1195	1215
13	1131	1139	1201	1082
14	1038	1221	1174	1193
MEAN:	1147	1234	1177	1171

(N.B. There are some minor discrepancies between means obtained from these analyses and those obtained by across-subjects anlyses; these small differences are attributed to round-off differences in the FOCAL program used to analyze data. In no case are the discrepancies large enough to concern us.)

The difference between column 1 and 2 means is significant (t=2.3, df=13); that between column 3 and 4 means is not significant (t=.29, df=13).

Table B-II. Experiment III; rhyme task

Word-group	LS-SS pairs	LS-SD pairs	LD-SS pairs	LD-SD pairs
1	1433	1798	1699	1650
2	1288	1645	1614	1543
3	1368	1431	1451	1752
4	1280	1774	1508	1796
5	1050	1713	1631	1823
6	1293	1765	1642	1747
7	1258	1735	1683	1503
8	1319	1616	1727	1804
9	1265	1745	1629	1787
10	1693	1735	1885	1730
11	1325	1746	1536	1668
12	1584	1844	1857	1599
13	1435	1772	1576	1648
14	1272	1815	1730	1701
MEAN:	1347	1724	1655	1701

The difference between columns 1 and 3 is significant (t=8.53, df=13); that between columns 2 and 4 is not (t=-.55, df=13).

Table B-III. Experiment III; letter-identity + rhyme task.

Word-group	LS-SS pairs	LS-SD pairs	LD-SS pairs	LD-SD pairs
1	1454	1685	1347	1363
2	1416	1816	1318	1350
3	1486	1790	1577	1323
4	1356	1755	1310	1339
5	1021	1618	1283	1026
6	1342	1836	1308	1447
7	1481	1630	1352	1376
8	1428	1559	1297	1370
9	1443	1659	1538	1344
10	1509	1728	1563	1383
11	1218	1845	1245	1338
12	1644	1880	1669	1546
13	1400	1770	1385	1384
14	1285	2101	1400	1420
MEAN:	1392	1762	1399	1358

Table B-IV. Experiment VII; letter-identity task.

Word-group	Homophones LS-SS pairs	LD-SS pairs	Nonhomophones LS-SS pairs	LD-SD pairs
1	906	973	888	916
2	896	986	1050	965
3	1002	994	892	1040
4	855	921	1044	957
5	985	1024	998	948
6	900	973	944	979
7	960	983	993	969
8	1005	931	945	1012
9	975	1007	895	981
10	928	1045	983	1013
11	979	1020	1023	933
12	981	887	963	936
13	927	918	908	942
14	1061	974	908	982
15	888	1010	992	1094
16	962	976	946	913
MEAN:	951	976	961	974

Table B-V. Experiment VIII; letter-identity task

Word-group	Homophones LS-SS pairs	LD-SS pairs	Nonhomophones LS-SS pairs	LD-SD pairs
1	1088	1066	1028	1118
2	1070	1103	1079	1174
3	1108	1314	1098	1162
4	1071	1157	1081	1143
5	990	1084	1099	1110
6	1134	1193	1041	1193
7	1066	1243	1048	1158
8	1142	1165	1123	1134
9	1032	1166	1022	1134
10	1133	1157	1013	1199
11	1068	1171	1180	1135
12	1017	1119	1052	1122
13	1004	1101	984	1095
14	1197	1176	1126	1254
15	1109	1242	1121	1242
16	1048	1091	1101	1098
MEAN:	1080	1159	1075	1154

Table 3-VI. Experiment IX; letter-identity task.

Word-group	LS-SS pairs	LS-SD pairs	LD-SS pairs	LD-SD pairs
1	800	725	798	823
2	793	765	793	767
3	786	823	879	952
4	800	823	822	821
5	615	714	640	705
6	702	648	806	758
7	797	692	765	783
8	705	755	790	807
9	979	962	988	937
10	762	680	771	751
11	721	796	781	763
12	804	816	838	868
13	690	763	766	777
14	685	757	770	874
MEAN:	760	766	801	813

Table B-VII. Experiment III; comparisons between the three tasks, across word-groups.

Stimuli	What is being compared.				
	Letter-Identity		Letter-identity + Rhyme		Rhyme
LS-SS pairs	1147	t = 10.61	1392	t = 1.51 *	1347
LS-SD pairs	1234	(nc)	1762	t = .98 *	1724
LD-SS pairs	1177	t = 8.47	1399	(nc)	1655
LD-SD pairs	1171	t = 6.42	1358	t = 7.11	1701

All t values refer to comparisons of the numbers between which they occur in a row, and all have df = 13.

"(nc)" between a pair of numbers indicates that it was inappropriate to compare the times, since a different response was demanded for one of the tasks than for the other for that particular stimulus type.

* This value of t is not large enough to permit the conclusion that these numbers differ significantly.

Appendix C: Error analyses. The number of errors are reported as decimal fractions.

Table C-I. Experiment III; comparisons between the three tasks, across subjects. Errors are reported as decimal fractions.

Stimuli	What is being compared.				
	Letter-identity		Letter-identity + Rhyme		Rhyme
LS-SS pairs	.07	t = 1.4 *	.05	t = 1.7 *	.02
LS-SD pairs	.06	(nc)	.22	t = 2.6	.26
LD-SS pairs	.04	t = .83 *	.07	(nc)	.14
LD-SD pairs	.04	t = .05 *	.04	t = 4.0	.25

All t values have df = 15.

"(nc)" indicates comparison of the numbers between which it occurs is not appropriate because of different response requirements.

* This value of t indicates that these numbers do not differ significantly.

The large difference in error rate between rhyme and letter-identity + rhyme condition can be accounted for in a number of ways, indicated in the discussion section of Experiment III.