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On the nature of phonological recoding in early readers

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On the Nature of Phonological Recoding

in Early Readers

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ABSTRACT

A major assumption in research on basic processes in word recognition has been that the phonological code which may be utilized to access meaning from printed text is unitary in nature and is always disrupted by articulatory suppression. Recent evidence however, suggests that at least two separate phonological codes are operative in adults. Besner, Davies and Daniels (1981), and Besner and Davelaar (1982) found that while the phonological code which supports the maintenance of information in short-term memory was affected by suppression, the code which supports lexical access was not. A developmental study by Barron and Baron (1977) relied heavily on the assumption that suppression disrupts a single phonological code. Consequently, their conclusions that children use only an orthographic code even in the early stages of reading may be incorrect. It is possible that children like adults are also able to use a phonological code unaffected by suppression. The present study was designed to investigate this possibility. Children from grades 2, 4, and 8 performed three separate matching tasks with and without articulatory suppression. The tasks comprised a picture-picture matching task, a picture-pseudohomophone rhyme matching task (e.g. a picture of a coat with the letter string BOTE), and a picture-pseudohomophone matching task (e.g. a picture of a cat with the letter string KAT). On some of the trials the children counted aloud from 1-10 while performing these tasks. The remaining trials were performed silently. Evidence for the presence

in the children of a phonological code unaffected by suppression was demonstrated by an effect on errors of suppression in the psuedohomohone-rhyming task in conjunction with no effect on errors of suppression in the pseudohomophone-matching task. These results suggest that data obtained from previous experiments which have used the suppression technique to assess the presence/absence of phonological recoding are uninterpretable.

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Overview

The recent finding that adults can make use of two distinct phonological codes during reading (Besner, Davies, and Daniels, 1981), rather than a single phonological code as has previously been assumed, may have important implications for the interpretation of previous research in reading and word recognition. The purpose of the present study is to determine whether two such phonological codes are also used by young children. If they are, then present theories of how adults and children read and/or learn to read will require some alterations.

The introduction of this thesis is divided into several sections. The first section reviews theories and data relevant to the question of how readers access the meaning of the words they read. The general conclusion from this research is that readers can rely on either a visually-based representational code or a phonological code. The second section reviews recent evidence that adults have available at least two speech-based codes. The third section reviews some research examining access codes in children, and questions the conclusions reached by researchers in light of their assumption that only a single phonological access code is available. The final section presents the rationale and outline of the present study.

General Introduction

How does a reader obtain meaning from print? Two methods of deriving meaning from a printed word have been postulated by numerous researchers. The first method, which has been labelled the "indirect path", involves the construction of a sound representation. This is analogous to listening to and deriving meaning from speech. This method of internal representation of words has been termed "phonological recoding" (e.g. Davelaar, Coltheart, Besner and Jonasson, 1978; Dennis and Newstead, 1981; McCusker, Hillinger and Bias, 1981). The second method is referred to as the "direct path". Here a purely orthographic association between the printed word and meaning occurs. This method bypasses a sound representation and is seen as the more frequently used of the two methods by fluent readers (Baron, 1973; Baron & McKillop, 1975; Coltheart, Davelaar, Jonasson & Besner, 1977; McCusker et al., 1981). Fluent adult readers appear to rely more on an orthographic code than a phonological code, except under the following circumstances. First, when access using the orthographic code is slow or does not occur, as with non-word letter strings (Seidenberg, Waters, Barnes & Tannenhaus, 1984). Second, it may be used when the ability to use the orthographic pathway is impaired, as is the case in patients suffering from surface dyslexia (Coltheart, Masterson, Byng, Prior & Riddoch, 1983). For a summary of the evidence supporting the use of these two codes in adults see Barron (1978), Jorm and Share (1983), McCusker, Bias and Hillinger (1981).

Recent research has also focused on the developmental acquisition of the two codes, motivated in part by the implications these findings have for teaching reading skills. Specifically, if the phonological code is the first to develop, then perhaps the method of teaching reading skills should emphasize the phonology of a word. In contrast, if the orthographic code is the first to develop, then perhaps a whole-word method should be employed. It is important to note that, at present, the research focused on questions of acquisition has been based on the assumption that there is only a single phonological code used in the reading process.

Recently, the suggestion has been made that adult readers utilize two separable phonological codes. Besner, Davies and Daniels (1981), and Besner and Davelaar (1982) found evidence for the operation of at least two phonological codes in adults, one that is affected by articulatory suppression, while the other is not. Articulatory suppression involves engaging the subject's speech apparatus, in an unrelated task, while the subject is reading (e.g. counting from 1-10 over and over). Researchers (e.g. Baddeley, Thomson and Buchanan, 1975; Barron and Baron, 1977; Levy, 1975; etc.) have used this technique on the assumption that suppression prevents the transformation of visual information into a phonemic code.

> ...suppression stops the visual to auditory transformation...articulatory suppression does not prevent rehearsal, but simply inhibits the translation of visual material into a phonemic code... (Baddeley et al., 1975, p.586).

The possibility that readers can utilize a phonological code which is unaffected by articulatory suppression casts doubt on any research using the suppression technique as a means of assessing the presence or absence of phonological recoding. The possible misinterpretation of experimental results is particularly evident in a study by Barron and Baron (1977), which uses the articulatory suppression technique to make specific inferences regarding basic processes in the development of reading skills. Because the possibility that two phonological codes may be present in readers poses a potential problem for Barron and Baron's interpretation, that study will be examined in greater detail below.

<u>Evidence for two phonological codes in adults.</u>

The assumption that only a single phonological process is available for use when one is reading has been favoured until recently (see Barron & Baron, 1977; Besner, in press; Besner & Davelaar, 1982; Besner et al., 1981; Kimura & Bryant, 1983). Paralleling this assumption was the utilization of the suppression manipulation as a means of studying this process. Recently, the use of suppression as a means of interfering with the phonological code has come under severe criticism. It has been argued instead that more than one phonological code exists, and that suppression affects these codes differentially (Besner & Davelaar, 1982; Besner, et al., 1981).

Besner, Davies, and Daniels (1981) report a series of experiments that examined the assertion that articulatory suppression disrupts phonological recoding of visually presented letter strings. Two types of experimental tasks were utilized. The first was a phonological lexical decision task (does this letter string sound like a real word?: e.g. BRANE-yes, BRONE-no), while the second type was a rhyme decision task using both words (e.g. CHOIR-FIRE) and non-words (e.g. PLOON-LEWN, NANE-TAYNE). Besner and his colleagues argued that in order to establish whether suppression interferes with the use of phonology, the experimental task must require the use of a phonological code.

In the phonological lexical decision task experiment, subjects were asked to decide whether a presented letter string sounded like a real word or not. None of the items were spelt like real words, but half of them sounded like real words (e.g. BRANE). If suppression disrupts phonological recoding, then subjects should take longer to go through such a list and/or make more errors while suppressing, than when they go through the lists silently. A failure to find a suppression effect would suggest that suppression is not disrupting phonological recoding. The results showed that suppression did not lead to either longer reaction time (RT), or more errors (Besner et al., 1981, Experiment 6).

This result is in sharp contrast with the results obtained in a study conducted by Baddeley, Thomson and Buchanan (1975). Baddeley et al. (1975) found, in a memory span experiment using visual presentation, that the superior recall of short words over long words (i.e. one syllable vs. three syllable words) was completely eliminated if the subject was required to suppress. This effect was not observed if the words were auditorily presented (i.e. short words retained their superiority in recall over the long words). The interaction between modality of presentation and suppression suggests that the word length effect is phonologically driven. Auditory presentation already provides a subject with the necessary phonemic information required for the short-term memory task. If the suppression technique only prevents transformation of visual information into a phonemic code, suppression could not interfer with information that was already presented in a phonemic form. Suppression effectively eliminated the difference between short and long words when the presentation was visual, thereby indicating interference between orthographic input and phonemic output. Without phonology the advantage of the short words was eliminated. This would leave a subject with only orthographic memory to recall items, which would hold "chunks" of information despite the amount of information in a chunk (Baddeley et al., 1975). The pattern of results just described suggest that the word length effect is phonemically driven.

The dissociation between the two studies is inconsistent with the theoretical position of those authors who hold that suppression prevents the transformation of visual information into a sound representation for the purpose of lexical access (e.g. Baron, 1977;

Barron & Baron, 1977; Kleiman, 1975; Martin, 1978; Smith, 1976). If phonological recoding is disrupted by suppression then the phonological lexical decision task should have been affected by the suppression manipulation. Besner et al. (1981) interpreted this dissociation as evidence for the existence of at least two phonological codes, one which is affected by suppression while the other is not. Besner et al. (1981) suggested that one of these codes may be used for lexical access and that this particular code is not sensitive to the effects of suppression.

In a subsequent study, Besner and Davelaar (1982) argued that a stronger case for the existence of two phonological codes could be made if the operation of these two codes were demonstrated within a single experiment. To that end, the authors utilized the memory span paradigm in conjunction with the assumption that both the phonemic similarity effect (e.g. Baddeley, 1966; Conrad, 1964; Richardson, Greaves, and Smith, 1980) and the word length effect (Baddeley et al., 1975) are mediated by a speech-based code. This assumption was based on the observation that a phonemic similarity effect occurs when a phonologically confusable set is used in place of a phonologically distinct set (e.g. FOOD, RUDE, and SUED vs. FALL, LOAF, and READ). In the former case the number of items recalled in the correct order is greatly reduced. A similar pattern of results occurs when long words (measured in terms of the number of syllables) are used in place of short words. Recall of short words is typically superior. However, when these tasks are presented visually to a subject, and the subject is asked to suppress, both these effects are eliminated (e.g. Baddeley, Thompson & Buchanan, 1975; Murray, 1967; Richardson et al., 1980). The fact that suppression eliminates both the word length effect and the phonemic similarity effect has been interpreted as evidence that "suppression stops the transformation of a visual stimulus into a phonemic code." (Baddeley et al., 1975, p.585).

Besner and Davelaar (1982) reasoned that since suppression did not prevent lexical access for pseudohomophones in the phonological lexical decision task, (Besner et al., 1981) then pseudohomophones should also be better recalled than nonpseudohomophonic nonword controls in a span task by virtue of the fact that a representation in the lexical-semantic system could be accessed and therefore support recall. If at the same time the phonological similarity and word length effects can be completely eliminated by suppression, then the results would support a dissociation between two phonological codes.

Besner and Davelaar (1982) report two span experiments. In the first they examined pseudohomophones and controls in conjunction with a phonemic similarity manipulation; in the second experiment they examined pseudohomophones and controls in conjunction with a manipulation of word length.

Their first experiment showed that while the phonological similarity effect was completely eliminated by suppression for both pseudohomophones and control items, the advantage in recall for the pseudohomophones over the nonword controls was maintained under the suppression condition. The results for Experiment 2, manipulating word length, produced the same pattern. That is, while the word length effect disappeared when the subjects suppressed, the advantage of pseudohomophones over controls was maintained.

These results support the hypothesis of two dissociable phonological codes. In both experiments, suppression eliminated the effects associated with utilization of some form of speech based code. At the same time, suppression did not affect another phenomenon that also had a phonological basis (i.e. the superior recall of pseudohomophones over non-words which do not sound like real words). This was seen as evidence for a phonological code unaffected by suppression which could access the lexicon. Thus both experiments support the claim that there are at least two phonological codes.

The suggestion that there is a phonological access code unaffected by suppression is particularly relevant to the interpretation of the results of two studies examining lexical access procedures in children (Barron and Baron, 1977; Kimura and Bryant, 1983). Those authors based their conclusions on the assumption that the phonological code which can be used to access the lexicon is sensitive to suppression. The purpose of the present study is to re-assess the possibility that, even in young children, there may be a phonological code that is not sensitive to suppression. How this may affect the conclusions reached by Barron and Baron, (1977), and Kimura and Bryant, (1983), will be examined in the following section.

Evidence for the visual-access route in children

Two theories have attempted to account for the chronological development of the two lexical access codes. The first hypothesis, the phonological recoding hypothesis, supposes that word-meaning access in beginning readers is mediated only by a speech-based code. However, as fluency develops, an orthographic code is slowly established in addition to the phonological code. There are three studies consistent with this hypothesis (Backman, Bruck, Herbert & Seidenberg, 1984; Doctor & Coltheart, 1980; Reitsma, 1983). Their importance to the issue addressed in the present thesis is minimal, thus they will not be considered further. The second hypothesis, the orthographic recoding hypothesis, states that access is based on an orthographic representation and that phonological recoding is a by-product of the training one receives while learning to read. Three studies are consistent with this view (Baron & Barron, 1977; Condry, McMahon-Rideout & Levy, 1979; Kimura & Bryant, 1983). Because the Barron and Baron (1977), and the Kimura and Bryant (1983), studies are critical to this thesis, they will now be reviewed in detail.

Barron and Baron (1977) asked whether the relative efficiencies of the phonological and visual codes change across age levels.

Children from five different grade levels (grades 1,2,4,6, and 8) were given two tasks, a sound task and a semantic task. In both, children were given several lists consisting of five picture-word pairs. In the semantic task the children were asked to point to the pairs in the list that went together (e.g. a picture of "ball" with the word "bat"). In the sound task the children were to point to the pairs in which the word rhymed with the subject of the picture (e.g. a picture of "corn" with the word "horn"). The dependent measures were the time (to the nearest second) it took for a child to go through a list, and the number of errors of commission or omission per list.

Barron and Baron made three types of comparisons to assess the changes that the phonological route might undergo as children grow older. First, they examined the ratio of sound to meaning task response times. They expected that children would generally show a decreased RT in both tasks as they grow older. However, they expected that developmental changes would also be observed in the sound to meaning task ratio. Specifically, if children changed from a phonological to an orthographic code in the meaning task as they grew older, then there would be a switching from a slow access code to a faster access code. Switching to a faster access code in the older age groups would lead to relatively faster RTs in the meaning task compared to the sound task, thus increasing the sound task to meaning task ratio. Thus while it was expected that both tasks would show a decrease in response times as age increases, a significant interaction between grade and task type was also critical to this comparison since it would suggest a shift in emphasis from the phonological code to the orthographic code in the meaning task. A lack of an interaction, which the authors did not expect, would suggest equal improvement in the use of the two codes across all age levels, suggesting that a developmental shift from a phonological to an orthographic code does not occur.

The second comparison they made was between the two tasks conducted with or without articulatory suppression. In this study, suppression consisted of repeating the word "double" over and over, while viewing the card on which the picture-word stimuli were printed. This technique has been shown to affect performance on tasks which have a phonemic component (e.g. Kleiman, 1975; Levy, 1975; Murray, 1968), and is argued to exert this effect by interfering with the mechanisms needed to utilize a phonological code. Therefore, if children change codes as they get older, one would expect the effect of suppression to decrease with age in the semantic task relative to the sound task. In other words, young children should show a suppression effect in both the rhyme task and the meaning task since they would be relying on phonology to perform both tasks. The older children would still show an effect for suppression in the rhyme task. However, since they would be able to use the orthographic code in the meaning task, no effect of suppression was expected.

The final comparison involved the distractor items. Under the confusable condition the distractor items would have been the correct choices in the alternative task (e.g. in the sound task a distractor item might be hook-"fish", a correct item in the meaning task; similarly a distractor in the meaning task would be a correct item in the sound task as in train-"rain"). The non-confusable items were not related to the pictured object either phonologically or semantically (e.g. squirrel-"gum"). If a gradual acquisition of the orthographic code occurs as a child grows older, one might expect an increasing effect of semantic confusability on the sound task and a decreasing effect of sound confusability on the meaning task.

The results of the study were as follows. First, the interaction between the task and age variables was not significant and the ratios of the RTs for the sound-to-semantic tasks were identical across all five age groups. As noted earlier, if children were switching from an phonological to an orthographic code as they grew older, this ratio should have shown a steady increase. The lack of the predicted Age X Task interaction does not support the notion that children gradually shift from relying on a primarily phonological to a primarily orthographic lexical access code as they become more fluent readers.

Articulatory suppression did not exert any main effect on the response times across age groups in either the semantic or the sound tasks. However, there was a significant effect for suppression in the error data: suppression produced significantly more errors than the silent condition in the sound (rhyming) task but it did not produce more errors in the meaning task. While there seemed to be a trend towards this effect diminishing with age, the age X task X interference interaction was not significant. These results are damaging to the phonological recoding hypothesis, since they suggest that since suppression had no differential effect across age in the semantic task, none of the children were using sound representations to access meaning. Thus, even the youngest children appeared to be using the orthographic code in order to gain access to word meaning in the semantic task.

Finally, the use of confusable as compared to non-confusable distractor items produced slower response times for all grade levels in both the semantic and sound tasks. This was supported by a main effect for confusability and by a failure to obtain any interactions between grade, task, and confusability. The same pattern of results was observed in the error data. These data, then, also do not support a developmental shift from a phonological code to an orthographic code in lexical access.

In summary, these results did not support the original expectations of the authors who felt that the experimental design would confirm a developmental shift from a phonological to an orthographic code. Because the lack of evidence of this developmental shift was apparent with three sets of manipulations, Barron and Baron abandoned the phonological recoding theory in favour of the orthographic access hypothesis, even for very young children who are just learning to read.

Further evidence that young children are able to use an orthographic code to access word meaning comes from a study by Kimura and Bryant (1983). The authors noted that Japanese children learn to read two different types of scripts, "kana" and "kanji". Kanji is a logographic script, each visual character symbolizing a word. Thus a Japanese student reading kanji script must rely solely on his or her orthographic memory. Kana, on the other hand, is a syllabary; each symbol signifies a syllable, and the symbol-sound relationships are entirely regular.

Kimura and Bryant examined the effects of articulatory suppression (counting from 1-5 in Japanese) on both types of scripts. The authors proposed that because kanji is a logographic script which could be comprehended without reference to any speech-based processes it might be unaffected by articulatory suppression. On the other hand, they proposed that because kana is a syllabic script, which is widely assumed to be read only by recourse to phonology (e.g. Sasanuma, 1980, 1984) this script might be interfered with by suppression.

In their study, grade one Japanese children were asked to perform a picture-word sorting task. A picture and a Japanese word (written in either kana or kanji) appeared on a single card. There were 10 cards in a deck, and the children were asked to sort the cards into a 'yes' (or same) pile and a 'no' (or different) pile on the basis of semantic identity. The children's responses were timed for each deck and the number of errors per deck was also recorded.

An additional factor of visual confusability was also part of the design. Visual confusability in the kanji script condition involved the use of two symbols that shared the same strokes except for one. In the kana condition, visually confusable syllabic names were drawn from a set of symbols that were found to be confusing for five and six year old children (see Tanaka, 1974 for details). A three-way interaction between script, articulatory suppression, and visual confusability was not expected since this would suggest that either visual information plays a role in what is strictly a sound task (i.e. reading from kana script) or sound information plays a role in what appears to be strictly a visual task (reading the kanji script).

The results supported the predictions by demonstrating that the picture-word cards written in the kana script took significantly longer to sort when the subjects engaged in articulatory suppression than under the silent condition, although there was no effect of visual confusability. The kanji script task displayed the opposite results: there was no effect for articulatory suppression, however the decks of cards with visually confusing items took much longer to sort than those without such items.

Kimura and Bryant (1983) performed a similar study using grade one English children, with the limitation that the script factor could not be included since there is only one script in English. Visually confusable words looked visually similar to the object in the picture, sharing the same initial letter and overall shape (eg. a picture of a HOUSE paired with the printed word HOURS). The results demonstrated that visual confusability interfered with the children's performance on the picture sorting task with or without articulatory suppression. Articulatory suppression did not affect children's ability to sort cards, and the interaction between visual confusability and suppression was not significant. This pattern of results resembles those of Barron and Baron (1977) and suggests that even young children are able to utilize an orthographic code for lexical access.

Taken together, the results demonstrate that grade one English children apparently use a orthographic code when reading script. Further, the results from the Japanese children demonstrate that reading Kanji (an orthographic script) is unaffected by articulatory suppression, while suppression does affect Kana which relies on a speech-based code.

The relevance of the Besner et al. (1981), and Besner and Davelaar (1982) studies to the interpretation of the results obtained by Barron and Baron(1977), and Kimura and Bryant (1982) is straight forward. If adults can use two phonological codes, is it possible that children have the same capacity? If young readers do have two phonological codes available, it may be that they are using the lexical access code which is unaffected by suppression. This possibility renders the Barron and Baron (1977), and the Kimura and Bryant (1982) results uninterpretable. The purpose of the present study is to determine whether a phonological code unaffected by suppression is available to children. The experiment designed to answer this question is discussed in greater detail below.

Rationale for the present experiment

In light of the evidence reviewed above the present investigation attempts to determine the presence of two phonological codes in young readers. This general question can be reformulated as two more specific questions. First, is it the case that young children have two phonological codes available or, alternatively, is it the case that the younger children have available only a single phonological code while the older children can benefit from the availability of two such codes? This latter outcome seems possible since it may be that the second phonological code which is insensitive to suppression develops as a child progresses from beginning to fluent reading.

In order to answer these questions, the picture-word matching procedure used by Barron and Baron was employed. However, this task was modified so that all letter-strings used were pseudohomophones, for example BRANE, TREA, KAR and so on. Performing a matching procedure using pseudohomophones forces the subject to phonologically recode the letter strings to gain access to word meanings. If suppression interferes with the transformation of orthographic information into a phonemic code, then performance on any task using pseudohomophones should be disrupted when suppressing. A task unaffected by suppression would question the conclusions of Barron and Baron, (1977), and Kimura and Bryant, (1983). This will later be examined in detail.

The pattern of results that would provide evidence for two phonological codes in children, one affected by suppression while the other is not, would be the same pattern of results observed in adults. Besner et al. (1981) and Wilding and White (1985), examined the RT and error rates of adults making rhyme decisions to visually presented pairs of letter strings while they were either suppressing or quiet. The results showed an effect of suppression for both dependent measures. Subjects took longer to go through a list, and they made more errors when they were suppressing, compared to the quiet condition. Besner et al. (1981) also used non-words and found an effect of suppression for the error data, but not for the RT data. The children in the present study are therefore also expected to display a suppression effect in the rhyme matching task either for RT, error rate, or both RT and error rate.

Adults making homophony judgments exhibit a different pattern of results. Baddeley and Lewis (1981) had subjects decide whether or not a non-word sounded the same as a word with which it was paired. The authors measured RT and error rates when subjects were either suppressing or quiet. The results showed that suppression did not increase either the RT's nor the error rates compared to the quiet condition. A phonological lexical decision task in Besner et al. (1981) produced similar results. The task involved distinguishing pseudohomophones from nonpseudohomophic control nonwords while they were either suppressing or quiet. Subjects did not take longer, nor did they commit more errors when they were suppressing compared to the quiet condition.

In this study the focus will be placed on the error data results. This is because in previous studies (e.g., Besner et al., 1981), RT results did not provide as clear a pattern of results as did errors. In earlier research, errors were analyzed as a percentage of responses. However, the present study's error analysis was conducted in two separate ways. First, errors as a percentage of responses is presented. Secondly, errors are divided into two types: misses and false alarms. A "miss" is defined as a matching pseudohomophone-picture pair (e.g., for the rhyme task, pseudohomophone--KAT, picture--BAT) which a subject fails to identify as a positive pair. A "false alarm" is defined as a pseudohomophone-picture pair that does not match but is identified by the child as a positive pair. An assessment of these two error types will prove to be empirically interesting, since other researchers have never examined this issue. Indeed, Wilding and White (1985), intended to carry out an analysis with misses and false alarms, but an oversight in data collection prevented completion of this analysis.

The children will be asked to perform two tasks requiring phonological recoding: a picture-pseudohomophone rhyme task (eg. picture of a star paired with the letter-string KAR), and a picture-pseudohomophone matching task (picture of a car paired with the letter-string KAR). The terms rhyming task and homophony task will be applied to these two tasks respectively throughout the remainder of this thesis. These two tasks will be performed under both silent and articulatory suppression conditions. A simple picture-picture matching condition will also be included in an attempt to establish baseline performance, and assess any non-specific effects of concurrent articulation.

If young children are able to employ two phonological codes that are qualitatively different from each other from the beginning of the early stages of reading, then we expect them to be unaffected by suppression in the homophony matching task. Such a result would certainly leave Barron and Baron's (1977) data open to the possibility that the children may have been employing a phonological code in the semantic condition that was not affected by suppression. Thus the conclusion that young children were using an orthographic code in the task may be invalid. A further consideration is that a phonological access code insensitive to suppression may evolve out of the earlier one which is sensitve to suppression. If this is the case, then young children may display an effect for suppression in the homophony task while the older children will not.

A subsidiary issue which the present experiment addresses concerns the potential effect of varying suppression rate. As Besner et al. (1981) demonstrated, the rate of suppression can dramatically affect the results. Besner et al. (1981) performed two phonological lexical decision experiments such that in one, the subjects articulated as fast as they could, while in the second, subjects suppressed at a slower rate. The dependent measures in both were RT and the number of errors. The results contrasted sharply: the first experiment showed no RT effect but a strong error effect, while the second experiment showed neither an RT nor an error rate effect. Barron and Baron (1977) do not report any details pertaining to the suppression rate they employed. Consequently, if we are to interpret the results of any experiment employing the suppression technique, it would be instructive to collect further data on the potential effects of varying suppression rate.

The present study uses two rates of suppression in conjunction with the three tasks described above. Both RT and error rate effects will be examined. If rate of suppression affects performance in children as it does in adults, the fast suppression condition might have an effect on the error rate but not on the RT measure. However, under the slower suppression rate, it is possible that there will be no decrement in accuracy.

METHOD

Subjects

Seventy-two children, 24 from each of grades 2, 4, and 8, were the participants. Three schools of the Waterloo County Board of Education were visited in order to fulfill the required number of subjects for each grade. All children were of average reading ability or better for their grade as reported by their teachers and all reported English as their first language.

Children were given a consent form for their parents to read and sign (see Appendix A). It was stressed that the children themselves must also be willing to participate before the parents signed the consent form. All children whose parents signed the consent form were entered into the study.

Design

The study was a 3(grade levels 2, 4, 8) X 3(picture-picture, rhyme, and homophony matching) X 3 (quiet, fast suppression rate, slow suppression rate) factorial design. The between-subject factor was grade level, while the within-subject factors were the three tasks and the three articulation conditions.

The order of the nine within-subject experimental conditions was randomized for each subject, however both rhyme and homophony picture-nonword paired stimuli were counterbalanced by an incomplete

Latin Square such that each letter string occurred in each condition. The picture-picture stimuli were separately counterbalanced by an incomplete Latin Square such that each picture pair occured in each condition. Appendix B lists the incomplete Latin Square counterbalancing for the stimuli.

Stimulus and Materials

The stimulus material used in the study consisted of 27 single page lists: 9 of the lists had five picture-picture pairs each, while the remaining 18 had five picture-letter string pairs. Each list was covered by acetate to protect it from wear and tear. The pictures were line drawings approximately 9 cm. wide X 6 cm. high. The letter strings were printed in lowercase and each letter was approximately 5 mm. square. All letter strings formed the pronunciation of objects that were familiar even to the youngest child as determined in an informal assessment by four children aged 5 to 8. For a list of the pseudohomophones used in this study see Appendix C. The pictures of the objects were pretested by the same method.

On each list of five pairs there were either two or three pairs that required a "yes" response. The non-matching items in the list were randomly assigned pictures and non-words. These pairs were not rhyming distractors. In addition, there were 9 practice lists, one preceding each condition. These practice sheets contained pairs that were separate from the actual test items and were not utilized as test material in the study.

The time taken to go through each list was measured by a digital stop watch that measures time to the 1/100th of a second.

Procedure

Each child was tested individually, at the school, in a separate quiet room. The initial task the children performed was to establish a fast and slow rate of suppression. The child was told to count from 1-10 as fast as he/she could for five seconds. The number of times each child counted from 1-10 was converted to the total number of items (e.g. if the child counts from 1-10 twice in the five second period, then the total number of items will be 20). From this total, the number of items the child was able to say per second was established (e.g. if the child was able to say a total of 20 items, then the number of items per second would be four). From this number a fast rate (i.e. 75% speed of the child's fastest rate; in the example above this would translate to 3 items per second), and a slow rate (i.e. 25% speed of the child's fastest rate; in the example this would be a rate of 1 items per second) was calculated. In the case of fractions, the number of items per second was rounded to the nearest whole number (e.g. if a fast rate of 3.72 items per second was calculated this would converted to four items per second). Appendix D contains a transcript of the instructions read to the child for this part of the study. In the experiment, when the child was required to suppress. the child counted from the beginning of the trial to the end of the trial at either the fast or slow rate. If the child was not able to maintain the proper rate of suppression specified, the experimenter reminded the child that they were either going too fast or too slow, and provided an example of the proper rate at which the child should be suppressing. While this was not a common occurence, a child would usually be reminded once during the course of the testing. This usually occurred during the early stages of the testing while the child was getting used to the dual task procedure.

After the rates of suppression were established the child was shown an example of a list accompanied by an explanation of the task. In addition the child was instructed that all the letter strings formed the pronunciation of words with which they would be familiar and examples were given. An example of each type of list is presented in Appendix E. The child performed the practice list of the relevant condition and any questions the child had were answered as clearly as possible. Timing for a trial began when a list was flipped over and the entire page was in complete view of the child. The timing ended when the child started to turn the list over. The task was to point to the pairs that go together according to the instructions supplied by the experimenter. This process was repeated for every condition. For a complete transcript of the instructions given to the child, refer to Appendix F.

During the experiment, the child was reminded of the task they were to perform before each block of three lists. In addition, the child was instructed as to the relevant articulation rate when they were not in the silent condition and were given an example of the rate, depending on the condition. The dependent measure was the time taken by each child to complete each list, and the number of errors made.

RESULTS

An analysis of variance for each task was conducted on the RT and the error data. As mentioned before, the error analysis was conducted in two ways. Combined errors were analyzed as well as two separate categories of errors: "misses" which occurred when a subject failed to identify a positive pair; "false alarms" which occurred when a subject mistakenly identified a pair as a match. The miss and false alarm error rates were calculated in the following manner. Each condition consisted of three lists, each of which had five letter string-picture pairs. From the three lists there were a total of eight pairs that matched and seven pairs that did not match. The miss rate was calculated by dividing the total number of matching pairs the child failed to identify by eight. The false alarm rate was calculated by dividing the number of unmatched pairs that the child identified by seven.

Analysis of both the RT and errors was conducted with data that had been adjusted by eliminating the outliers in the RT data. This process involved calculating the standard deviation for each condition, for each grade, using the RT data. Any single trial value that fell outside a range of plus or minus two standard deviations from the mean was eliminated. Errors committed on those trials were also excluded from further analysis, thus eliminating aberrant data. This procedure resulted in eliminating approximately 5% of the data collected across all conditions.

The adjusted error data were converted into proportions, followed by arcsin transformations. Errors reported in the tables are represented as percentage scores; the analyses of variance are based on transformed values. It should be noted that secondary error analyses were done without transformations to ensure that the results were not distorted by the transformations. The transformations did not alter any of the results, therefore the analysis without transformations will not be considered further.

Picture-picture task. A two-way analysis of variance on the RT's, misses, and false alarms in the picture-picture task was included to assess any non-specific effects of suppression once the data had been corrected for outliers.

Reaction time data. The average RT per grade for each condition is given in Table 1 and the upper left panel of Figure 1; the ANOVA summary table for the RT data is found in Appendix H. The analysis of variance revealed a main effect for Grade, $F(2,69)=41.74$, $MSe=5.29$, $p<.01$. The main effect of Suppression was not significant, $F(2, 138)=2.92$, $MSe=1.38$, $.05<p<.06$. The Suppression X

Grade interaction was not significant ($F<1$). The main effect of Grade reflects the fact that older children performed the task faster than younger children. A Fisher Least Significant Difference (LSD) test confirmed this trend. Grade 8 children were significantly faster than the grade 4 children, who were significantly faster than the grade 2 children.

The observation that the main effect of suppression approached significance was due to a decrease in RT when subjects suppressed (overall means were 6.63, 6.52, 6.18 for Quiet, Slow, and Fast conditions respectively). It would be premature to claim that a non-specific effect of suppression was not present in these RT data.

Error data - combined. The average percentage of combined errors for each condition per grade are given in Table 1 and the upper right panel of Figure 1; the ANOVA summary table can be seen in Appendix I. An analysis failed to yield significant effects for Grade ($F<1$) or the Grade X Suppression interaction, $F(4, 138)=1.22$, $MSe=.003$, $p>.05$. The main effect of Suppression was significant, $F(2, 138)=7.53$, $MSe=.003$, $p<.05$. A Fisher LSD test showed that the significant differences were between the slow suppression rate and both the quiet condition and fast suppression rate. The difference between the quiet and fast suppression conditions was not significant.

Error data-misses. The average percentage of misses for each condition for each grade are given in Table 1 and the lower left

TABLE 1

MEAN RT, COMBINED, MISS, AND FALSE ALARM RATES AS

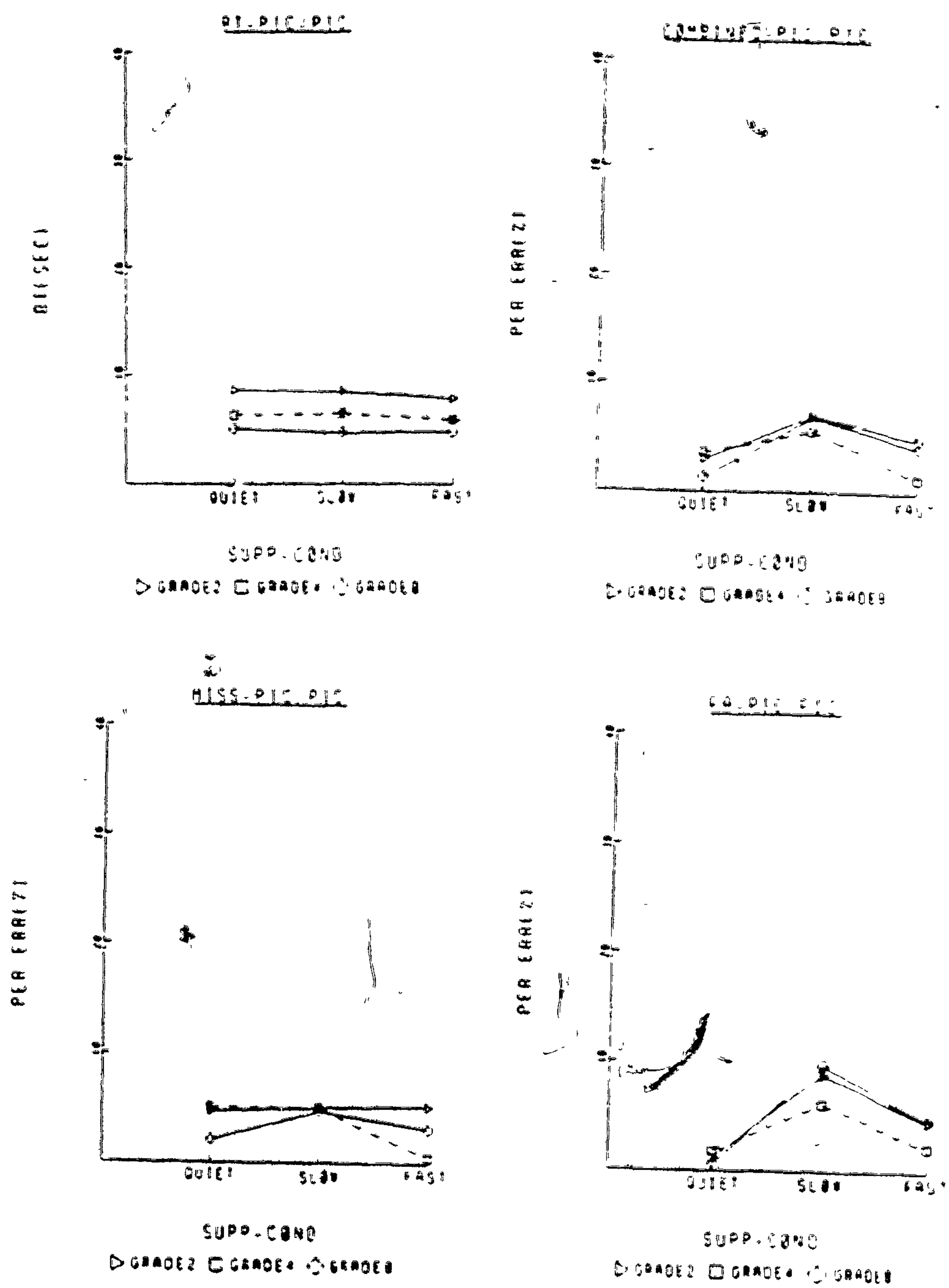
A FUNCTION OF GRADE, AND SUPPRESSION FOR THE PICTURE-PICTURE TASK

	GRADE								
	GRADE 2			GRADE 4			GRADE 8		
TASK	Q	S	F	Q	S	F	Q	S	F
RT(SEC)	8.59	8.45	7.85	6.30	6.44	5.91	5.00	4.67	4.77
(SD)	2.09	2.62	2.26	1.10	1.51	0.87	1.48	0.72	0.93
COMBINED( )	3.05	6.92	4.84	3.60	5.54	1.24	1.38	6.78	4.14
(SD)	6.80	7.48	6.73	6.20	6.92	2.90	3.38	9.24	4.72
MISSES( )	4.69	5.03	5.21	5.03	5.00	0.52	2.08	4.69	3.13
(SD)	9.62	9.82	9.69	9.11	8.53	2.55	4.76	8.89	5.53
FALSE ALARM	1.19	8.94	4.62	1.79	6.20	2.23	0.60	9.77	4.72
( ) (SD)	5.83	10.17	9.68	4.83	8.67	6.30	2.92	13.89	9.11

SUPPRESSION CONDITION
Q=QUIET
S=SLOW
F=FAST

SD=STANDARD DEVIATION

Figure 1 Mean RT, percent combined errors, percent miss errors, and percent false alarm errors for the picture-picture matching task as a function of grade and suppression


MISS-PIC-PIC
PER ERR(%)
QUIET SLOW FAST
SUPP-COND
GRADE2 GRADE4 GRADE8

panel of Figure 1; the ANOVA summary table can be seen in Appendix J. An analysis of variance failed to yield significant effects for Grade, ($F<1$), Suppression, $F(2,138)=1.10$, $MSe=.006$, $p>.05$, or the Grade X Suppression interaction, $F(4,138)=1.05$, $MSe=.006$, $p>.05$.

It can be concluded that the suppression manipulation did not have any non-specific effect on the number of misses in the picture-picture matching task.

Error data - false alarms. The average percentage of false alarms for each condition for each grade are given in Table 1 and the lower right panel of Figure 1; the ANOVA summary table can be seen in Appendix K. An analysis of variance failed to yield significant effects for Grade, or for the two-way interaction between grade and suppression (F's < 1). However, the main effect of Suppression was significant, $F(2,138)=14.15$, $MSe=0.00625$, $p<.01$. A Fisher LSD test showed that the significant differences were between the slow suppression rate and both the quiet condition and fast suppression rates in the picture-picture task. The difference between the slow suppression rate and the other two articulatory conditions is due to an increase in the false alarms when subjects are suppressing slowly. This increase seems to be evident across all three grades.

Since the misses data do not show a non-specific effect of suppression in the picture-picture task, and since the fast suppression rate also does not lead to an increase in the number of false alarms, the increase in false alarms under the slow suppression rate is unexpected and does not seem to have a logical explanation. The evidence strongly favours the hypothesis that suppression does not affect the error rates dramatically as a function of any non-specific effects. A theoretical basis for the selective effect of the slow rate on the false alarm data does not exist at this time.

In conclusion, because suppression does not display any dramatic effects on the error measures in the picture-picture task, it seems safe to conclude that any effects of suppression which may be found in either the Rhyme or Homophony tasks will not be due to any non-specific dual task performance effects.

Rhyme task analysis. Following the elimination of trials on which the RTs were greater than two standard deviations above or below the mean, an average RT, combined error rate, miss error rate, and false alarm error rate, for each condition per subject were computed. Means for all four dependent variables for each condition across grade level are presented in Table 2 as well as Figure 2.

Reaction time data. The ANOVA summary table for RT is found in Appendix L. A two-way analysis of variance produced main effects for Grade, $F(2,69)=27.40$, $MSe=40.88$, $p<.01$, and Suppression, $F(2,138)=11.40$, $MSe=5.22$, $p<.01$. The interaction of Suppression X Grade was not statistically significant, $F(4,138)=2.10$, $MSe=5.22$, $p>.05$.

TABLE 2

MEAN RT, COMBINED, MISS, AND FALSE ALARM RATES AS

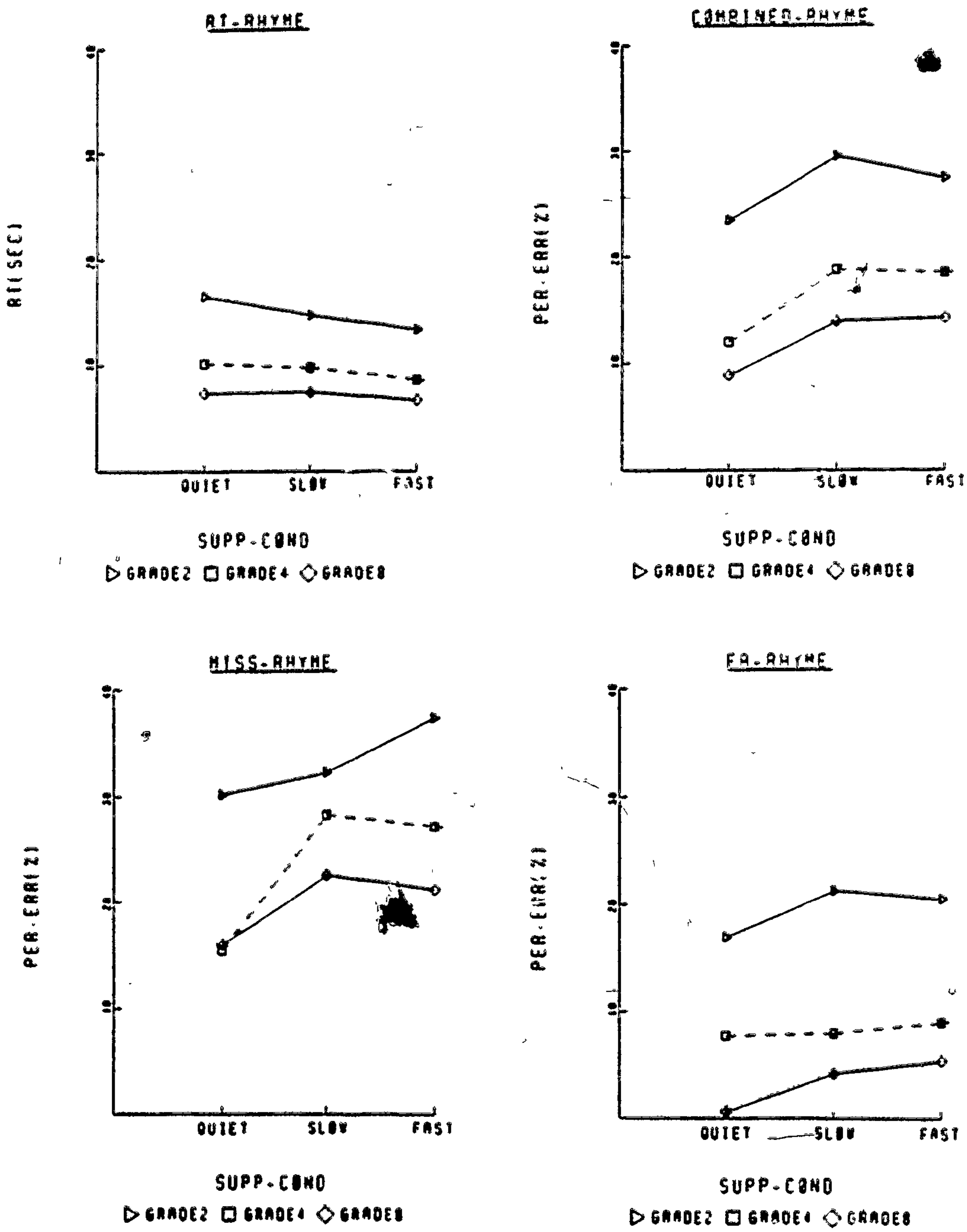
A FUNCTION OF GRADE, AND SUPPRESSION FOR THE RHYME TASK

	GRADE								
	GRADE 2			GRADE 4			GRADE 8		
TASK	Q	S	F	Q	S	F	Q	S	F
RT(SEC)	16.48	14.65	13.30	10.13	9.73	8.56	7.30	7.40	6.64
(SD)	6.92	6.79	5.46	2.26	3.25	2.15	1.73	2.04	1.63
COMBINED(%)	23.45	29.45	27.35	11.93	18.74	18.45	8.86	13.87	14.13
(SD)	17.47	12.93	18.81	11.47	10.63	11.40	7.96	10.77	8.82
MISS(%)	30.24	32.26	37.33	15.45	28.30	27.15	15.98	22.57	21.15
(SD)	19.61	12.95	22.89	14.14	16.98	17.68	14.83	16.89	16.43
FALSE ALARM	16.91	21.28	20.45	7.75	7.98	8.94	0.60	4.17	5.36
(%) (SD)	21.75	24.15	26.37	13.32	13.48	12.52	2.92	8.92	8.23

SUPPRESSION CONDITION
Q=QUIET
S=SLOW
F=FAST

SD=STANDARD DEVIATION

Figure 2 Mean RT, percent combined errors, percent miss errors, and percent false alarm errors for the rhyme matching task as a function of grade and suppression


RT-RHYME
RT(SEC)
QUIET SLOW FAST
SUPP-COND
GRADE2 GRADE4 GRADE8
COMBINED-RHYME
PER-ERR(%)
QUIET SLOW FAST
SUPP-COND
GRADE2 GRADE4 GRADE8
MISS-RHYME
PER-ERR(%)
QUIET SLOW FAST
SUPP-COND
GRADE2 GRADE4 GRADE8
FA-RHYME
PER-ERR(%)
QUIET SLOW FAST
SUPP-COND
GRADE2 GRADE4 GRADE8

A Fisher LSD test was conducted for each main effect. The LSD test on the Grade main effect indicated that performance by the children at the grade 2 level was significantly slower than the other two grade levels (14.81 vs. 9.47, 14.81 vs. 7.11, LSD=3.65). The difference between the grade 4 and grade 8 children was not significant.

The Fisher LSD indicated that the Suppression main effect was due to the fast condition producing a quicker RT than either the slow suppression condition, or quiet condition (11.30 vs. 9.50, 10.59 vs. 9.50, LSD=0.75). There was no significant difference between the slow suppression and the quiet conditions.

These results are somewhat surprising in that the RT data was not expected to reveal an improvement in performance when the children suppressed in the fast condition. The RT data for the slow and quiet conditions is more in line with the results from other studies. This interesting result in conjunction with the RT data from the picture-picture task will be further examined in the discussion.

<u>Error data - combined.</u> The percentage of errors for each subject, under each condition, was calculated. The average percentage of errors per condition across grade levels are available in Table 2 and the upper right panel of Figure 2. The ANOVA summary table for combined errors is found in Appendix M.

An analysis of variance indicated main effects for Grade, $F(2,69)=16.14$, $MSe=.027$, $p<.05$, and Suppression, $F=(2,138)=5.85$, $MSe=.013$, $p<.05$. The Grade X Suppression interaction was not significant ($F<1$).

A Fisher LSD test indicated that the Grade main effect was due to a significant difference in the number of errors made between the grade 2 children and the grade 4 and grade 8 children (.276 vs. .167, .276 vs. .125, LSD=.095). The difference between the grade 4 and grade 8 children was not significant. A Fisher LSD test for the suppression main effect showed that when children were in the quiet condition they made fewer errors than when they were in the slow and fast suppression conditions (.152 vs. .211, .152 vs. .205, LSD=.039). The difference between the slow and fast suppression conditions was not significant.

This pattern of results replicates those of Wilding and White (1985) in adults. The next two sections will determine if this pattern of results changes when the errors are divided into two categories.

Error data-misses. The total number of misses for each subject, for each condition was summed and converted into a proportion. The average proportion of errors per condition across grade levels are available in Table 2 and the lower left panel of Figure 2. The ANOVA summary table for misses are found in Appendix N.

An analysis of variance indicated main effects for Grade, $\underline{F}(2,69)=9.21$, $\underline{MS}e=.044$, $p<.01$ and Suppression, $\underline{F}(2,138)=5.06$, $\underline{MS}e=.031$, $p<.01$. The Grade × Suppression interaction was not statistically significant ($\underline{F}<1$).

A Fisher LSD test indicated that the Grade main effect was due to a significant difference in the number of errors made between the grade 2 and grade 8 children (0.350 vs. 0.205, LSD= 0.120). The grade 4 children made neither significantly more errors than the grade 8 children, nor significantly less than the grade 2 children. A Fisher LSD for the suppression main effect showed that while there was a difference between the Quiet and the Slow conditions, and between the Quiet and the Fast conditions (0.214 vs. 0.286, 0.214 vs. 0.300, LSD=0.058) the difference between the slow and fast suppression rates was not significant.

The pattern of results between the suppression and the quiet conditions is identical to that observed in adults (Wilding and White, 1985). Suppression increased the number of misses compared to the quiet condition, however the difference between the slow and fast suppression conditions was not significant. The second part of the error data, the false alarms, must now be considered

<u>Error data-false alarms.</u> The number of false alarms was totalled in each condition for each child. This total was converted into proportions in the same way as the misses. The average proportion of false alarms in each condition for each grade level is

listed in Table 2 and the lower right panel of Figure 2. As with the miss errors, an arcsin transformation was used on the false alarm proportions. These transformation values were used in all further analyses. The ANOVA summary table for false alarms is found in Appendix O.

An analysis of variance indicated a main effect for Grade $F(2,69)=8.58$, $MSe=.066$, $p<.01$, but not for Suppression, $F(2, 138)=1.58$, $MSe=.014$, $p>.05$. The Suppression X Grade interaction was not significant ($F<1$).

A Fisher LSD test indicated that the Grade main effect was due mainly to a significant difference between the grade 2 children and the grade 8 children (0.212 vs. 0.040, LSD=0.147). The grade 4 children did not make significantly fewer errors than the grade 2 children, nor significantly more errors than the grade 8 children.

Homophony task analysis. Once again, trials whose RTs were greater than two standard deviations above or below the mean for both the grade level and articulatory condition, were eliminated. Mean RT, and error proportions were then calculated for each condition, per subject. The means for each condition are presented in Table 3, as well as Figure 3. Arcsin transformations were used in the analysis for both types of errors.

TABLE 3

MEAN RT, COMBINED, MISS, AND FALSE ALARM RATES AS

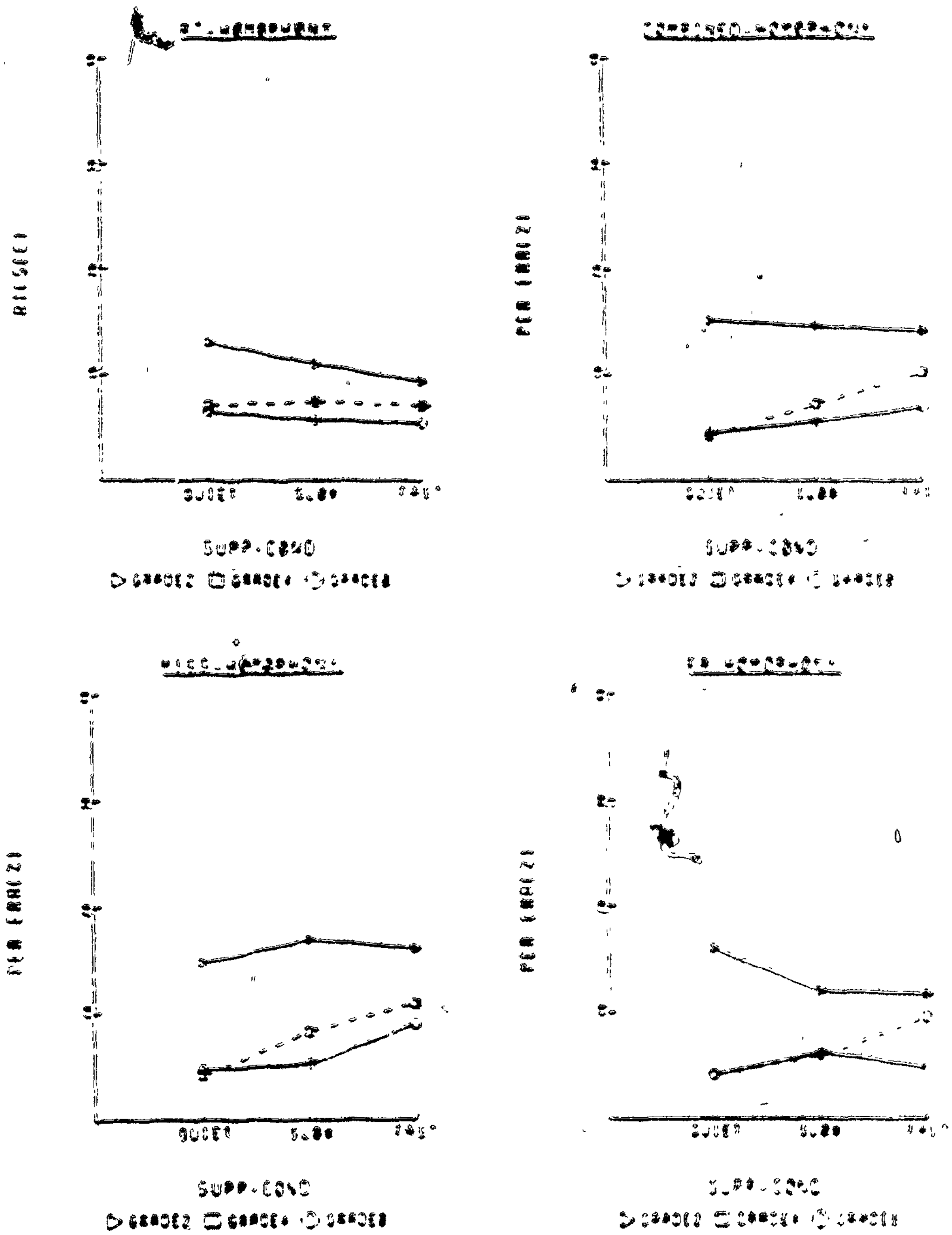
A FUNCTION OF GRADE, AND SUPPRESSION FOR THE HOMOPHONY TASK

	GRADE								
	GRADE 2			GRADE 4			GRADE 8		
TASK	Q	S	F	Q	S	F	Q	S	F
RT(SEC)	12.98	10.92	9.26	7.09	7.36	7.02	6.47	5.62	5.33
(SD)	4.90	2.79	2.10	1.17	1.63	1.58	2.93	1.05	0.99
COMBINED(%)	15.12	14.57	14.15	4.15	7.21	10.25	4.42	5.53	6.92
(SD)	14.08	11.72	11.69	7.03	8.55	12.90	5.06	7.26	8.89
MISS(%)	14.69	16.77	15.94	4.17	8.16	10.76	4.69	5.21	8.85
(SD)	16.09	15.40	15.32	8.77	12.74	12.58	8.09	8.17	12.49
FALSE ALARM	15.92	11.91	11.62	4.17	5.96	9.53	4.17	6.25	4.77
(%) / (SD)	17.02	16.14	15.32	8.92	10.26	16.67	7.87	12.16	10.04

SUPPRESSION CONDITION
Q=QUIET
S=SLOW
F=FAST

SD=STANDARD DEVIATION

Figure 3 Mean RT, percent combined errors, percent miss errors, and percent false alarm errors for the homophony matching task as a function of grade and suppression



Reaction time data. The ANOVA summary table for RT is found in Appendix P. A two-way analysis revealed main effects for Grade, $F(2,69)=49.68$, $MSe=10.75$, $p<.01$, and Suppression, $F(2,138)=13.83$, $MSe=3.53$, $p<.01$, as well as a Suppression X Grade interaction, $F(4,138)=6.23$, $MSe=3.53$, $p<.01$.

A Fisher LSD test indicated that the interaction was due to the fast suppression condition producing significantly faster RTs than the slow suppression condition, which in turn, was faster than the quiet condition (12.98 vs. 10.92, 10.92 vs. 9.26, LSD=1.07) at the grade 2 level All of these differences disappeared at the grade 4 level. At the grade 8 level the difference between the fast suppression condition and the quiet condition was the only one that was significant (5.33 vs. 6.47, LSD=1.07).

The suppression facilitation effect in the RT data, seen in the rhyme task is also evident in the homophony task. While this result is somewhat surprising, there is some evidence that the result in the RT data is not specific to the tasks at hand, but instead a result of the suppression manipulation itself.

Error data - combined. The percentages of combined errors per condition across grade level in the homophony task are available in Table 3 and the upper right panel of Figure 3. The ANOVA summary table for combined errors is found in Appendix Q.

An analysis indicated a main effect for Grade, $F(2,69)=9.58$, $MSe=.017$, $p<.05$. A Fisher LSD test indicated that grade 2 children made more errors than grade 8 children (.150 vs. .060, LSD=.075). The grade 4 children did not make fewer errors that the grade 2 children nor did they make more errors than the grade 8 children. The Suppression main effect, $F(2,138)=1.66$, $MSe=.007$, $p>.05$, and the Grade X Suppression interaction, $F(4,138)=1.13$, $MSe=.007$, $p>.05$, were not significant.

<u>Error data-misses.</u> The calculation and analysis of the homophony miss data was conducted in the same manner as the rhyme miss data. The ANOVA summary table for misses is found in Appendix R.

A two-way analysis indicated a main effect for Grade, $F(2,69)=7.76$, $MSe=.025$, $p<.01$, but not for Suppression, $F(2,138)=2.45$, $MSe=.011$, $p>.05$. The Grade x Suppression interaction was not significant ($F<1$).

A Fisher LSD test indicated that the Grade main effect was due to a significant difference between the grade 2 children and the grade 8 children (.164 vs. .068, LSD=.090). The grade 4 children did not make fewer errors than the grade 2 children, nor did they make more errors than the grade 8 children.

When the above pattern of results is compared to the pattern observed in adults a striking similarity is apparent. In adults, suppression increased the number of errors in a rhyme task (Wilding and White, 1985), however suppression did not increase the number of errors in a homophony task (Baddeley and Lewis, 1981). The results

Both the total error analysis and the miss error analysis appear to support the hypothesis that two separate phonological codes are operational in children. The implications of this result will be further explored in the Discussion section below.

<u>Error data-false alarms.</u> As with the rhyme data, proportions for the homophony false alarm data was calculated in each condition, for each child. In addition, the analysis was conducted in the same manner as the false alarm rhyme data. The ANOVA summary table for false alarms is found in Appendix S.

The analysis displayed a main effect for Grade, $F(2,69)=4.81$, $MSe=.028$, $p<.05$. A non-significant result was obtained for the Suppression main effect ($F<1$) and the Grade X Suppression interaction, $F(4,138)=1.37$, $MSe=.013$, $p>.05$. The main effect of Grade reflects fewer false alarms at the grade 8 level compared to the grade 2 levels. The grade 4 children did not differ from either the grade 2 children, nor the grade 8 children.

DISCUSSION

The purpose of the present study was to determine whether children, like adults, have available to them two separate phonological recoding procedures rather than a single process as has previously been assumed. An alternative possibility also examined in the present study was that younger children might have available only a single phonological code, while the older children might have available two such codes. That is, is there evidence of a developmental trend from a single phonological code into two separate phonological codes, or is there evidence of two pnonological codes operating at a very young age?

In this discussion, the error data will be examined first, with an interpretation of the misses followed by an interpretation of the false alarms. Next, the RT data will be examined. The RT data deserves some attention because of the suppression variable's surprising facilitative effect in both the rhyme and homophony tasks. The discussion will be concluded by an examination of the role of suppression rate in studies with young children.

This study paralleled the Barron and Baron (1977) paradigm, except for one critical change. In place of words, pseudohomophones were used so that the subjects in the present study were assumed to use a phonological code to perform the two tasks. It is possible that in the Barron and Baron (1977) study, phonological recoding did not occur since their use of familiar words may have allowed the children to read using an orthographic code, having learned initially to read the words using a phonological code. This would have led to the observed results in the Barron and Baron (1977) study. However, an alternative interpretation of their results may be proposed; if children have available two phonological codes, one of which is not sensitive to suppression, then the lack of a suppression effect in their data does not permit their conclusion that phonological recoding was not playing a role in the children's performance in the semantic task. They may well have been using a phonological code which is not affected by suppression.

The rationale for the present study was as follows. There would be strong evidence of two phonological codes in children if they produced the same pattern of results as adults in a rhyme and homophony task. The pattern in the adult literature is straight forward: suppression increased the number of errors when judging whether or not a word pair rhymed (Wilding & White, 1985), however suppression did not increase the number of errors when making a homophony judgment (Baddeley & Lewis, 1981).

The pattern of the errors in this study replicates the pattern observed in the adult literature. A main effect of suppression was observed in the rhyme task in both the combined and miss error rates. Further analyses determined that this difference was between the quiet condition and the two suppression conditions for both error measures, although the error rates between the fast and slow suppression conditions did not differ. The homophony task provided evidence that is crucial to the proposal that a phonological code exists which is unaffected by suppression. For this task, the data analysis for both combined and miss error rates indicated that there was no main effect of suppression. Further there was no interaction between suppression and grade. This latter result indicates that a developmental trend did not occur, and that the child's ability to use a phonological code unaffected by suppression was evident for even the youngest children in the sample.

The implication of this result is apparent to the interpretations of both the Barron and Baron (1977), and Kimura and Bryant (1983) studies. Their conclusions were based on the assumption that readers have available only a single phonological code which is always affected by suppression. Clearly, the results of the present study imply that children in the previous two studies may have been utilizing a phonological code which is unaffected by suppression in performing the semantic tasks. The conclusions of the above two studies are therefore questionable. A critical consequence of the present results is that the use of the suppression technique as an experimental tool to detect the presence or absence of phonological recoding for the purpose of lexical access must be abandoned.

Until recently the suppression manipulation has been utilized because of its assumed disruption of the formation of a phonological code. This method has been used extensively by numerous researchers based on the above assumption. However, the combined results of both the present study and that of Besner et al. (1981), and Besner and Davelaar (1982), provide evidence of the availability of a phonological code unaffected by suppression in both adults and children. Consequently, the results of studies which have employed the suppression technique with a view to disrupting phonological recoding become uninformative. Specifically, a lack of a suppression main effect in a reading study could be attributed to one of two possibilities; either subjects are using an orthographic code, or the subjects are using a phonological code unaffected by suppression. A researcher will be unable to resolve this conflict. Until this issue has been further examined, it is clear that it is unwise to use suppression as a means of determining the presence or absence of phonological recoding.

Why does the rhyming task show an effect of suppression in both the combined and miss error rates while the homophony task does not? Besner et al. (1981) and Besner (in press) propose that when making a rhyme or homophony nonword judgment, the phonological representation of the letter string is first assembled. The difference between the two tasks occurs after the phonology is assembled. A rhyme judgment must rely on further segmentation and deletion processes on the phonological whole so that a comparison between letter strings can be conducted. Homophony judgments, on the other hand, do not rely on these processes. Besner (in press) proposed that suppression interferes with the segmentation and deletion processes, thereby increasing the number of errors of ommission committed in the rhyme task. Conversely, since these processes are not required in a homophony task, the lack of a suppression effect is not suprising.

The false alarm data provided a different pattern of results. The main effect of suppression was not significant in either the rhyme or homophony tasks. Since suppression does not seem to affect the false alarm error rate. we need not consider these data further here.

The RT data yielded rather unexpected results. In the homophony task, grade 2 children were facilitated in performance by the suppression manipulation as they performed the tasks. When making comparisons from the quiet condition to the slow to the fast suppression conditions progressively shorter RTs are indicated. This facilitation was not observed in the grade 4 children, and only in the fast suppression condition for the grade 8 children. By contrast, in the Rhyme task the suppression main effect showed that the fast suppression rate produced significantly quicker RTs than either the slow rate condition or the quiet condition for all grade levels.

It is obvious from the above pattern of results that RT data in children is not a consistent measurement. It is interesting to note in passing that while a large number of studies examined in this thesis have shown either a decremental or no effect at all on RT of suppression on a primary task, there is at least one study that has shown suppression facilitating the primary task (e.g. Kinsbourne & Cook, 1971).

One possible explanation for suppression facilitating RT may lie in the use of pseudohomophones in place of words. The children in the present study were forced to assemble a phonological code, and children probably lack the experience to form the phonology of an unfamiliar letter string without considerable effort. In the quiet condition the children may have taken extra time in an attempt to ensure the proper assembly of the nonword's phonology. Coupling suppression with the experimental tasks may have acted as an internal metronome, quickening the pace of the children's performance. Thus, the faster they counted, the faster they performed the task.

If this process were occurring, one might expect a speed/error trade-off due to the child not allowing himself the time to properly form the phonological representions, leading to an error. While the results do show an increase in the number of misses in the rhyme condition with suppression coupled with a decrease in RT, the possibility of a speed/error trade-off in the homophony data may be discounted. While this task resulted in a decrease in RT with suppression for grades 2 and 8, these two grades did not show a parallel increase in missed targets or false alarms. In other words, the grade 4 and 8 students displayed the same error pattern as the grade 2 children; however, they did not display the same facilitation effect in the RT data. Had there been a speed/error trade-off, one would have expected that the grade 2 children would have exhibited a significantly greater proportion of errors over and above the number of errors due to suppression, as the child progressed from quiet to slow to fast suppression conditions. This did not occur. A speed/error trade-off therefore cannot account for the combined pattern of results.

An alternative explanation for the facilitation of RT by suppression may be evident from the picture-picture results. A facilitation effect of suppression was also observed in this task. Thus the quickening of RT may simply reflect an effect due to the suppression manipulation that is not specific to the reading tasks. This might explain the overall results observed in the rhyme and homophony tasks, however further study will be needed.

A subsidiary issue which this study attempted to address was the effect of varying the suppression rate on the children's performance. Considering the results from both the RT and error data, it seems that varying the suppression rate had no appreciable effect. The error data showed that suppression did not affect the proportion of false alarms for either suppression rate in either task, nor did it affect the number of misses in the homophony task. In the Rhyme task the number of misses did not significantly differ between the slow and fast suppression rates. Thus, suppression rate does not seem to be a factor of concern when considering the error rates.

The RT data pattern showed that varying the suppression rate only affected the grade 2 children's performance and only on the homophony task. Here, the fast condition was faster than the slow condition. Taken together, the RT and error data seems to suggest that manipulating suppression rate has little differential effect.

Several methodological considerations for future studies in this area should be considered. First, a potential problem inherent in the use of pseudohomophones may be the operation of possible strategy effects. Taft (1982) presented evidence that subjects used grapheme-to-grapheme conversion rules instead of grapheme-to-phoneme conversion rules in a lexical decision task. He proposed that a strategy may be employed which allowed subjects to map a grapheme onto a common phoneme (e.g., PH=F, K=C). These mappings develop an ability to activate each other, eventually eliminating any reference to a phonological mediator. In other words, subjects would substitute a C for a K in the pseudohomophone KAT, to make CAT. Subjects would no longer need to form the phonology for the letter string KAT but instead could use the visual code for lexical access.

Besner, Dennis and Davelaar (1985), tested Taft's grapheme-to-grapheme theory in two experiments. The results showed that while pseudohomophones facilitated responses to subsequently presented words (e.g., GROCE--GROSS), nonword letter strings which were translatable into words through the application of grapheme-to-grapheme rules did not produce a facilitory effect (e.g., GLOCE--GLOSS). The latter results are inconsistent with the grapheme-to-grapheme conversion hypothesis, it would seem unlikely that such conversion rules would be used by the children in this study.

Further, it would be useful to analyze the test items used in such a study as this to determine if there are any patterns in the error reponses of the children. Items that constantly elicit an error response could be examined so that it may be determined if there is a fault in the construction of the pair (Note: this was not a problem in the present study since the items occured in all conditions). In relation to this point, a more extensive pretest of the stimuli would be in order than was possible for this thesis, due to time constraints. Extensive pretesting would reduce the possibility of faulty pairs being assembled, thus possibly reducing patterned error responses on specific items. Third, further analysis of the miss/false alarm error type distinction is required. The present thesis is the only attempt to date to distinguish between the two error types. Future researchers will determine if the distinction between these two error types contributes to the understanding of the reading process in both children and adults. Finally, a more exacting method of RT measurement would be beneficial. The problem of control over the timing procedure was apparent for this study. While other studies (e.g., Barron & Baron, 1977) may also have suffered from a timing control problem a better procedure is a challenge to future researchers.

SUMMARY

In summary, the results provide evidence that children do indeed have available two phonological codes at least as early as the grade 2 level. The implications of two phonological codes for the work of Barron and Baron (1977), and Kimura and Bryant (1983) are important. Their research was based on the assumption that there is but one phonological code and that it is always affected by suppression. In light of the present results, their data becomes uninterpretable. Finally, perhaps the most important conclusion to be drawn from the present results is that the suppression manipulation, long used as a technique to determine the presence or absence of a phonological recoding process, cannot be used to yield data to address that issue.

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APPENDIX A

Copy of the consent form

May 6, 1985

Dear Parent and Guardian:

A graduate student in our department, Mr. Tom Yoannidis, will be conducting a study with students in your child's class on reading. This Study has been approved by the Waterloo County Board of Education, but the final decision about participating in the research is up to you and your child. The purpose of the research is to increase our understanding of the development of the reading process.

The children will be presented with lists of pictures paired with either other pictures, or letter strings, which, when pronounced, sound like words (e.g., KAT). The three tasks will be (a) to point to pictures paired together which are the same, (b) point to the picture-letter string pairs which rhyme (e.g., picture of BAT paired with the letter string KAT), and (c) to point to the picture-letter string pairs which are the same (e.g., a picture of a cat with the letter string KAT). Further, on some of the lists, the children will be asked to count aloud from one to ten while performing the pointing task. It is hoped that these procedures will give us some insight into the nature of the reading process.

The students are seen individually for about 20 minutes during class time at the school. The scheduling arrangements are made through the Principal in cooperation with the teachers. In addition to parental consent, each child must be willing to participate and may stop at any time during the proceedings. The session is low-key, non-competitive, and is fun for the experimenter as well as for the student.

Although the results of individual children will not be made available, a written report detailing the general findings will be given to you through the school.

If you have any questions about this research, I would be glad to talk with you. Call me at 884-1970, Ext. 2314, and if I am not available, please leave a message for a return call. Please return the enclosed form to the school so that we know whether or not your child is to participate in the research.

Yours sincerely,

Eileen Davelaar, Ph.D.

Tom Yoannidis, B.A.

:hp
Enc.

I have agreed to have my child participate in the research on reading which is being conducted by Dr. Eileen Davelaar and Tom Yoannidis of the Psychology Department at Wilfrid Laurier University.

Yes_____

No_____

I understand that my child has the right to withdraw from the study at any time as well as the right to refuse to participate.

Parent or Guardian's Signature______________________________

Name of Child______________________________

Appendix B

Incomplete Latin square counterbalancing

INCOMPLETE LATIN SQUARE COUNTERBALANCING

Picture-pseudohomophone matches

	Task					
	Rhyme			Homophony		
	Condition					
Subject #	Quiet	Slow	Fast	Quiet	Slow	Fast
		Suppression			Suppression	
S1, S7, S13, S19	A	B	C	D	E	F
S2, S8, S14, S20	B	C	D	E	F	A
S3, S9, S15, S21	C	D	E	F	A	B
S4, S10, S16, S22	D	E	F	A	B	C
S5, S11, S17, S23	E	F	A	B	C	D
S6, S12, S18, S24	F	A	B	C	D	E

A, B, C, D, E, F represents sets of stimuli, each of which contains 7 positive matches, which were divided amoung 3 lists per set.

S1, S2, ...S24, represents the subject number who received the specified set under each condition.

Picture-picture task counterbalancing

Subject #	Condition Quiet	Slow Suppression	Fast Suppression
S1, S4, S7, S10, S13, S16, S19, S22	A	B	C
S2, S5, S8, S11, S14, S17, S20, S23	B	C	A
S3, S6, S9, S12, S15, S18, S21, S24	C	A	B

A, B, C represent the three sets of picture-picture stimuli, each of which contained 7 positive responses, which were divided amoung 3 lists per set.

S1,S2....S24 represents the subject number who received the specified set under each condition.

Appendix C

Pseudohomophones and their rhyme and picture pairs

Psuedohomophones	Rhymes	Pictures
KAR	STAR	CAR
GLOO	SHOE	GLUE
PARRET	CARROT	PARROT
BAIR	SQUARE	BEAR
RAIK	SNAKE	RAKE
SEEL	HEEL	SEAL
BALUNE	RACOON	BALLOON
PHROG	DOG	FROG
KLAW	SAW	CLAW
BOCK	SOCK	BOX
KYTE	LIGHT	KITE
NOZE	TOES	NOSE
NEE	KEY	KNEE
NERSE	PURSE	NURSE
KORN	HORN	CORN
PHAN	CAN	FAN
ROCKIT	POCKET	ROCKET
PHISH	DISH	FISH
KANDEL	HANDLE	CANDLE
WHAIL	PAIL	WHALE
PHLOOTE	BOOT	FLUTE
PEEZ	CHEESE	PEAS
KLOCK	ROCK	CLOCK
PADEL	SADDLE	PADDLE

PYE	EYE	PIE
FONE	BONE	PHONE
TRANE	CHAIN	TRAIN
KART	HEART	CART
DORE	FLOOR	DOOR
RIST	FIST	WRIST
HOWSE	MOUSE	HOUSE
MEDEL	PEDAL	MEDAL
NIKEL	PICKLE	NICKEL
PHORK	STORK	FORK
GAITE	SKATE	GATE
TYRE	FIRE	TIRE
KAT	HAT	CAT
KANE	PLANE	CANE
PHIN	PIN	FIN
ARROE	WHEELBARROW	ARROW
SNALE	NAIL	SNAIL
SKEE	BEE	SKI
WYCH	SWITCH	WITCH
TRUK	DUCK	TRUCK
KAGE	STAGE	CAGE
GOAST	TOAST	GHOST

Appendix D

Suppression Rate Instructions

SUBJECT INSTRUCTIONS

The first thing we are going to do, is to find out how fast you can count because this will be important for later. I want you to count from one to ten over and over as fast as you can for five seconds. When I say "GO" I will switch the timer on and you are to start counting. After five seconds you will hear the timer make a click sound and you will stop counting. (E demonstrates the clicking sound).

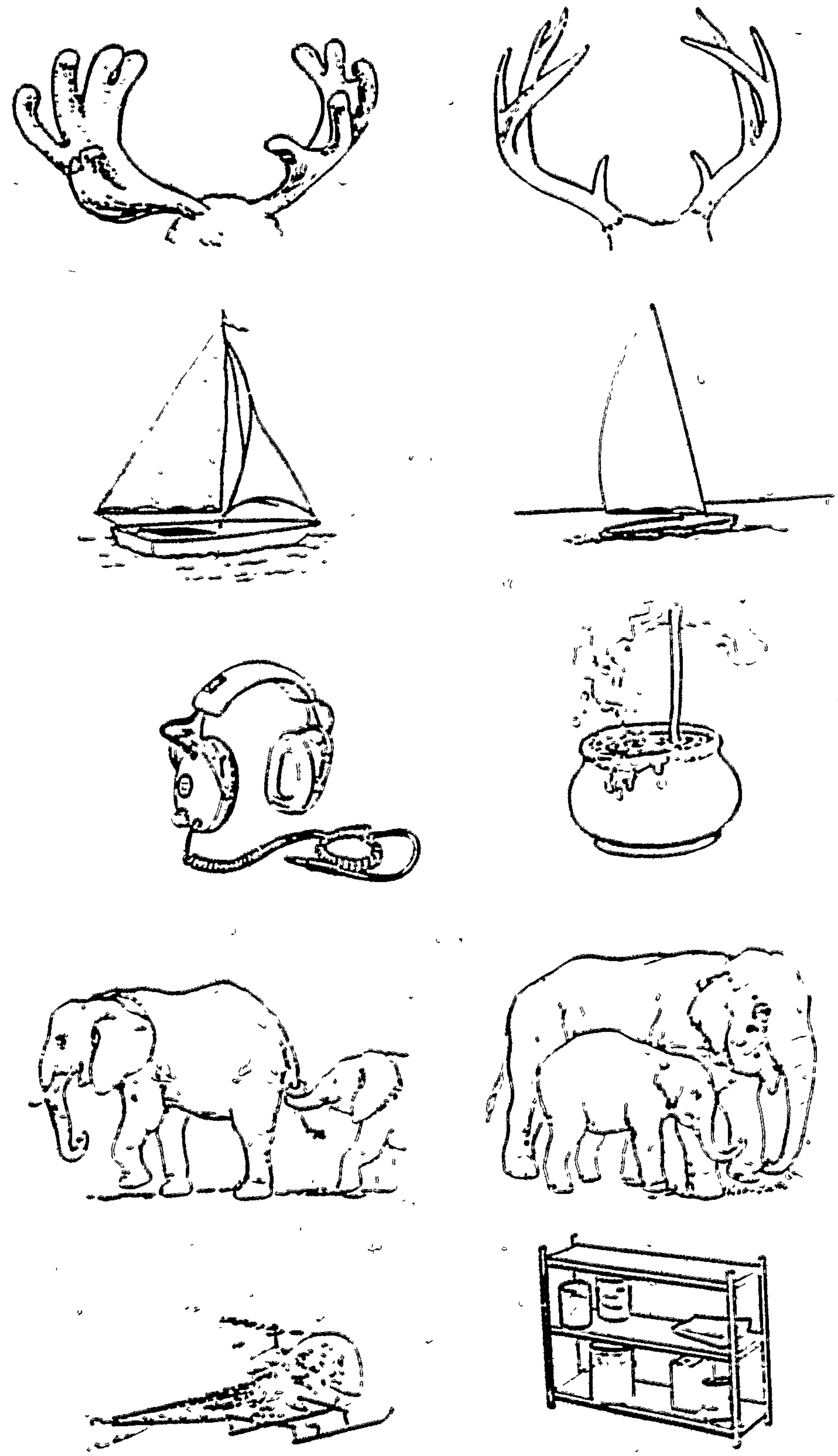
Do you have any questions?

Are you ready to go?

Note: For calculation of the suppression rates to be used in the experiment, see the Method section.

Appendix E

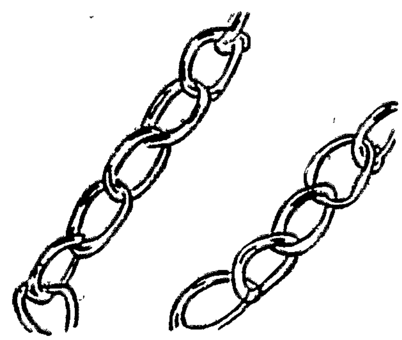
Examples of Picture-picture, rhyme, and homophony matching tasks lists



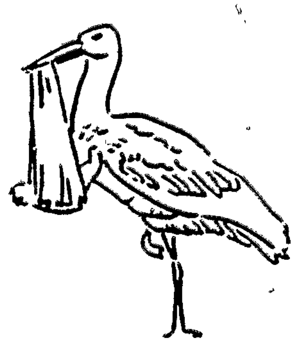
pye

kanew

trane



skwirel



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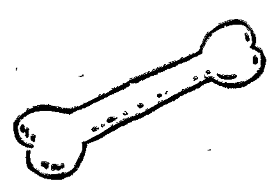
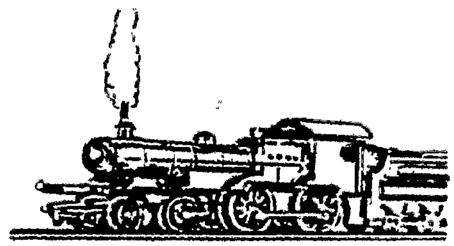


kammel

pye

trane



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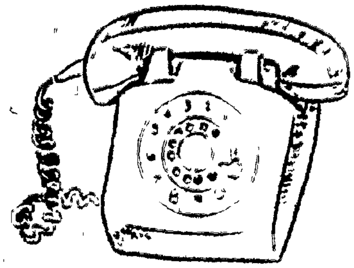
fone



Appendix F

Task Instructions

SUBJECT INSTRUCTIONS

Now we are going to do some things that you will have fun doing. What I am going to do is give you some cards that have pictures on them. Some of these pictures will have other pictures beside them, like this (E shows example of a picture-picture card), while the others will have some letters beside them (E shows an example of a picture-nonword card).

When you are using these cards with the two picture-pairs I want you to point to the pairs that are the same. So on this card you would pick the pairs with the two balls (E points to the pair) and the two cats (E points to this pair). I am going to see how fast you can go through a list so I am going to use this stopwatch and time you on each list. I will start timing you as soon as you flip over the card like this (E demonstrates), and I will stop timing you when you flip it over like this (E demonstrates). You will then wait for me to write down the time it took you to go through the list before you start on the next list. Do you have any questions?

When you get the cards with the pictures and letters you will have to look at the picture and read the group of letters. For one type of card you will decide if the name of the object in the picture rhymes with the sound the letters make. If it does you are to point to the pair. So on this card you would go down the list (E starts with the first pair, a picture of a PLOW and the letters

K-O-W which sound like COW when you say it). You would not point to this one because the sound the letters make (UNYUN) do not rhyme with the picture object (TELESCOPE). All these letters will make the sound of a word when you say it aloud. Now look at the next pair. Here there is a picture of a coat with the letters B-O-T-E. If you say that aloud, you should pronounce it like BOAT. Since these two rhyme you would point to this pair. Try the last three pairs on this card. (E lets child go through last three). Do you have any questions?

For the other type of cards you will have to look at the picture and read the letters and point to the pairs that have the letters making the same sound as the object in the picture. Look at this card (E shows a card to the child). The first pair has a picture of a cat and the letters K-A-T which sound like "CAT" when you say it aloud. Because the letters sound like the object in the picture, you would point to this pair. Now look at the next pair with a picture of a MITTEN and the letters OASHUN which sound like "OCEAN". Because these two do not sound the same you would not point to them. Try the other three pairs on the list (E lets child go through the last three pairs). Do you have any questions?

For some of these lists you will have to count from 1-10 over and over while you are going through the pairs. Each time you are to go through a list where you have to count I will show you how fast you are to count. It is important that you only count as fast as I tell you. You should start counting before you flip the card over, and you stop when you flip the card over again. Let me show you (E demonstrates).

You are to go through these lists as quickly as possible but try not to make any mistakes. If you do make a mistake, don't stop, just finish the rest of the list. You should also know that if you don't want to continue you can stop and go back to class whenever you want. Do you have any questions?

Let's get started. In the first set of lists you will go through you will have to match...

Appendix G

Raw data for RT

misses and false alarms

Average RT per condition, per trial, for grade two children

Subject#	Task: Picture-picture Quiet	Picture-picture Slow	Picture-picture Fast	Rhyme Quiet	Rhyme Slow	Rhyme Fast	Homophony Quiet	Homophony Slow	Homophony Fast
1	11.20	6.97	5.60	13.70	17.90	7.57	13.03	12.33	9.03
2	9.43	12.60	8.33	18.40	17.03	15.07	22.75	12.83	6.10
3	5.57	6.77	5.80	6.87	5.23	4.97	5.47	6.73	5.03
4	7.53	6.13	5.87	11.47	6.00	14.80	9.60	12.57	9.87
5	7.47	5.90	8.70	19.60	20.03	11.87	16.33	13.45	12.43
6	6.37	6.27	7.77	12.10	15.10	14.70	11.00	10.37	8.30
7	11.10	9.80	9.57	31.20	26.40	21.57	18.63	16.35	12.30
8	9.70	9.37	9.00	13.27	16.37	9.03	9.93	10.27	7.90
9	7.90	9.43	6.37	15.67	19.37	11.07	13.47	16.15	8.60
10	7.53	8.17	8.07	13.33	11.20	15.83	12.33	8.80	8.33
11	10.05	15.40	15.80	19.23	26.30	25.20	22.70	12.85	9.70
12	7.27	8.30	7.33	24.80	17.70	16.30	15.10	12.10	8.23
13	11.93	13.37	8.13	25.70	19.93	17.03	14.53	12.93	13.83
14	6.20	9.87	7.43	6.53	5.07	8.87	8.11	7.50	12.23
15	10.00	10.00	12.00	33.50	24.97	25.75	22.45	12.27	10.40
16	7.67	6.57	5.10	12.93	9.17	6.80	6.90	6.43	8.60
17	6.30	7.27	8.40	18.23	16.37	11.87	14.73	12.77	10.80
18	6.43	7.93	6.43	10.43	9.43	13.77	9.77	9.07	9.80
19	9.13	6.83	6.37	20.20	12.47	11.73	10.53	10.10	10.10
20	11.75	11.00	7.00	14.53	22.55	16.90	12.70	9.00	10.13
21	10.45	6.50	8.30	19.23	11.00	11.30	9.77	9.43	8.23
22	5.10	4.77	6.43	9.70	5.50	7.97	7.50	8.40	8.27
23	10.20	7.43	7.87	13.27	8.13	12.47	15.37	12.77	6.83
24	8.70	6.17	6.77	11.73	8.43	6.70	8.97	6.63	7.13

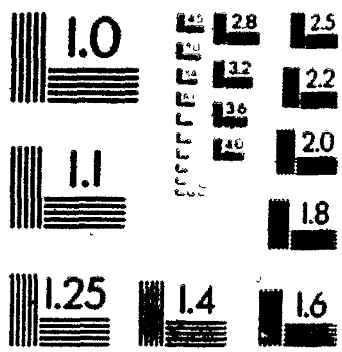
Average RT per condition, per trial, for grade four children

	Task								
	Picture-picture			Rhyme			Homophony		
Subject#	Quiet	Slow	Fast	Quiet	Slow	Fast	Quiet	Slow	Fast
1	6.57	9.80	8.10	12.77	11.73	10.17	8.27	9.80	9.95
2	7.93	7.00	5.63	12.63	9.00	10.83	7.83	6.23	6.83
3	6.50	6.60	6.90	11.93	11.33	9.63	5.57	6.80	6.70
4	6.10	7.20	6.43	8.77	10.87	7.87	7.97	6.00	8.70
5	5.70	6.53	5.97	15.60	17.53	11.40	8.23	10.00	8.90
6	5.40	5.10	5.90	10.37	9.17	8.30	8.17	7.27	8.07
7	6.43	4.23	5.27	8.90	8.67	7.90	7.40	9.27	6.43
8	8.07	6.50	5.40	10.03	10.63	9.93	8.23	6.25	6.30
9	6.93	5.60	5.47	10.77	7.60	7.00	7.70	6.57	6.47
10	5.3[illegible]	7.77	6.10	6.20	8.07	6.13	6.07	8.67	6.07
11	6.10	8.13	5.33	9.47	10.80	8.20	6.27	8.77	6.87
12	4.73	5.93	5.63	11.25	6.97	4.80	5.67	8.43	5.67
13	6.70	4.77	4.70	9.00	6.63	6.43	5.43	5.40	6.53
14	7.60	5.00	5.33	7.87	6.73	8.13	8.20	8.97	7.23
15	5.10	5.80	5.40	9.00	6.20	6.07	6.73	6.47	5.27
16	6.93	5.73	5.23	12.50	6.17	10.67	5.57	6.37	5.65
17	7.23	9.65	7.00	12.93	15.80	13.10	9.40	7.87	8.67
18	4.[illegible]3	4.70	5.87	10.63	6.13	6.10	5.87	5.00	4.83
19	6.17	6.27	6.37	8.77	15.85	10.45	7.33	7.07	7.87
20	5.33	6.07	5.93	10.17	8.87	8.93	6.33	5.40	7.70
21	7.97	8.80	7.40	11.05	11.37	11.93	7.43	11.00	11.10
22	7.00	6.07	6.33	9.30	8.83	6.80	8.47	6.20	6.20
23	6.80	6.53	6.07	7.37	12.40	6.60	6.40	5.97	5.80
24	4.25	4.67	4.00	5.93	6.10	8.07	5.73	6.97	4.87

Average RT per condition, per trial, for grade eight children

	Task								
	Picture-picture			Rhyme			Homophony		
Subject*	Quiet	Slow	Fast	Quiet	Slow	Fast	Quiet	Slow	Fast
1	3.50	3.85	3.97	5.73	4.27	5.50	3.87	4.15	4.93
2	3.53	3.57	5.73	4.77	5.97	5.57	5.03	4.90	3.97
3	4.77	3.93	5.23	5.70	5.53	4.97	4.30	4.50	5.33
4	3.67	3.67	3.93	6.57	6.70	5.27	4.60	6.57	4.37
5	4.23	5.33	3.85	6.53	5.50	6.63	6.40	7.23	4.57
6	5.85	4.47	5.83	8.40	9.27	6.80	7.03	6.33	5.50
7	4.70	3.97	3.90	5.03	4.83	5.40	4.17	4.50	5.10
8	3.07	3.80	3.50	5.33	7.77	4.87	4.07	4.50	5.60
9	3.10	4.23	4.67	5.93	4.40	4.80	4.77	3.73	4.33
10	7.23	5.97	5.92	7.60	7.93	9.30	12.50	5.27	6.23
11	4.93	4.63	5.03	6.93	5.50	6.03	5.93	[illegible]	4.57
12	7.63	5.60	6.60	11.00	10.70	10.90	16.50	7.80	8.60
13	3.80	3.85	4.17	7.27	7.20	5.70	4.10	6.63	4.56
14	5.03	5.27	5.23	8.93	11.40	7.03	9.67	6.93	6.33
15	3.33	4.40	3.50	6.47	7.47	6.57	5.17	5.67	4.63
16	5.85	4.73	5.47	10.10	8.30	8.23	6.77	6.63	6.43
17	6.60	[illegible]	5.70	11.05	5.83	5.80	8.97	6.03	4.73
18	4.17	4.50	4.55	7.13	7.67	5.73	5.07	4.97	5.20
19	6.67	5.35	4.53	6.13	7.23	6.83	6.33	5.30	4.93
20	7.30	5.50	3.80	7.30	8.17	6.93	5.37	5.77	5.23
21	4.37	5.00	4.93	6.82	8.60	5.57	4.97	4.53	4.67
22	5.20	4.23	3.40	7.77	9.10	9.50	6.87	5.33	5.63
23	4.53	[illegible]	4.97	9.00	11.60	9.05	6.90	6.50	6.33
24	5.07	5.60	6.10	7.55	6.97	6.37	5.57	5.40	5.83

2 of/de 2



Number of misses
for grade 2 children

Subject#	P	PS	PF	R	RS	RF	H	HS	HF
	Condition								
1	0	0	1	2	2	5	1	2	2
2	2	0	0	4	4	4	2/5	3	2
3	0	0	2	4	2	5	0	1	0
4	0	0	0	2	2	3	2	2	3
5	0	0	0	2	1	2	1	0	0
6	0	0	1	3	2	3	2	1	2
7	2	1	0	0	2	8	0	1/5	0
8	0	0	0	1	3	1	0	0	0
9	0	0	3	2	1	3	0	3/6	3
10	0	0	0	0	3	2	2	1	0
11	0	1/3	0	2	1/5	1/2	1/2	1/5	0
12	0	0	0	1	1	4	0	2	2
13	1	0	0	4/6	5	2	4	4	3
14	2	2	1	2	3	1	2	0	1
15	0	0	0	1/3	3	2/5	0	1	1/5
16	0	0	0	2	4	3	2	1	2
17	0	1	0	5	4	6	1	0	0
18	0	0	1	3	3	1	0	0	0
19	0	0	0	0	3	1	0	2	1
20	0	0	0	1	1/5	0	0	0	0
21	0	0	1	3	2/6	1	0	0	1
22	0	2	0	4	3	2	1	1	2
23	0	0	0	3	3	3	1	3	4
24	2	1	0	3	2	5	2	1	1

Note: All errors are out of eight possible chances unless otherwise specified (e.g. 2/6 would be two errors out of a possible six chances, the othe two chances having been eliminated by the procedure describe in the Results for eliminating certain trials)

P = Picture-picture task, quiet condition
PS = Picture-picture task, slow suppression condition
PF = Picture-picture task, fast suppression condition
R = Rhyme task, quiet condition
RS = Rhyme task, slow suppression condition
RF = Rhyme task, fast suppression condition
H = Homophony task, quiet suppression condition
HS = Homophony task, slow suppression condition
HF = Homophony task, fast suppression condition

Number of false alarms for
grade 2 children

Subject #	P	PS	PF	R	RF	RS	H	HS	HF
1	0	0	0	1	0	2	1	1	2
2	0	2	0	2	3	2	1/5	1	0
3	0	1	0	1	0	0	0	0	0
4	0	0	1	3	4	3	4	2	1
5	0	1	2	0	2	3	1	0	1
6	0	1	0	0	0	1	1	1	0
7	0	0	0	0	2	0	0	0	1/2
8	0	2	1/4	0	0	0	0	0	0
9	0	0	1	0	1	1	0	0	2
10	0	0	0	0	0	0	1	0	0
11	0	0	0	1	0	1/3	1/3	0	0
12	0	0	0	1	4	3	1	1	0
13	0	0	0	1/5	0	0	1	0	1
14	0	2	0	4	4	2	3	1	2
15	0	1	0	0	0	0	0	1	0
16	0	0	0	1	2	0	0	0	0
17	0	0	0	1	0	0	0	0	0
18	0	1	0	1	1	0	1	1	1
19	0	0	0	0	0	0	1	0	1
20	0	1	0	0	0	0	0	0	0
21	0	1	0	0	1/4	0	0	1	0
22	0	1	2	6	4	3	3	3	0
23	0	0	0	2	2	6	2	3	2
24	2	1	0	3	5	6	3	4	3

Note: All errors are out of seven possible chances unless otherwise specified (e.g. 1/4 would be one error out of four chances, due to trial elimination through the method described in the Results section)

Number of misses for the grade 4 children

Subject #	P	PS	PF	R	RS	RF	H	HS	HF
1	0	0	0	2	2	3	0	0	0
2	1	2	0	1	4/6	1	1	0	1
3	1	0	0	0	1	1	0	0	1
4	0	1/5	0	0	0	3	0	0	0
5	0	0	0	0	4	4/6	0	0	0
6	0	0	0	3	3	5	0	0	1
7	2	1	0	2	2	2	0	2	2
8	0	0	0	1	2	1	0	0	0
9	0	0	1	0	2	2	0	0	1
10	0	0	0	3	2	3	0	3	3
11	0	0	0	1	3	2	0	2	0
12	0	2	0	0	2	0	1	1	0
13	1/3	0	0	3	2	2	0	0	1
14	1	1	0	1	1	0	0	0	0
15	0	0	0	1	2	2	0	0	1
16	0	0	0	0	2	4	0	0	0
17	1	0	0	3	3	2/5	0	2	1
18	0	0	0	1	2	2	1	0	0
19	1	0	0	2	0	1/5	0	0	0
20	0	0	0	2	3	3	0	2/6	0
21	0	0	0	0	3	2	3	0	1/3
22	0	1	0	2/6	5	1	1	1	1
23	0	1	0	1	0	3	1	0	3
24	0	0	0	0	3	0	0	2	2

Note: All errors are out of a possible eight chances unless specified.

Number of false alarms for grade 4 children

Subject #	P	PS	PF	R	RS	RF	H	HS	HF
1	0	0	0	1	2	0	0	2	0
2	0	1	1	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	1
4	0	0	0	0	0	0	1	0	1
5	0	0	0	0	0	0	0	0	0
6	0	0	0	1	0	1	0	1	0
7	1	0	0	0	1	1	0	2	1
8	0	1	0	1	0	0	0	0	2
9	0	0	0	0	1	2	0	0	0
10	1	0	1/4	1	1	2	2	0	4
11	0	0	0	0	0	0	0	0	0
12	0	1	0	0	1	1	0	2	0
13	0	0	0	1	0	0	0	0	0
14	1	2	0	0	1	0	0	0	1
15	0	1	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	1/5	0	0	0	0	0	0	0
18	0	1	0	0	1	2	0	0	0
19	0	1	0	2	1/5	0	1	1	1
20	0	0	0	3	4	1	0	0	0
21	0	0	0	0	0	1	1	0	0
22	0	0	0	0	0	0	0	1	0
23	0	1	1	3	0	3	2	1	4
24	0	0	0	0	0	1	0	0	1

Note: All errors are out of a possible seven chances unless specified.

Number of misses for the grade 8 children

Subject #	P	PS	PF	R	RS	RF	H	HS	HF
1	0	0	0	1	0	0	0	0	0
2	1	1	0	2	0	0	1	0	0
3	0	1	0	0	1	1	0	0	0
4	1	1	0	1	1	0	0	0	0
5	0	0	0	0	3	0	0	0	0
6	0	0	0	0	1	1	1	0	0
7	0	2	0	0	1	2	2	0	2
8	1	2	0	2	4	3	0	0	0
9	0	0	0	1	1	2	0	1	0
10	0	0	0	2	1	1/5	0	0	1
11	0	0	0	2	4	4	0	2	0
12	0	0	0	0	1/3	1/3	0	0	0
13	0	0	1	1	0	2	0	0	1
14	0	0	0	0	3	1	0	0	0
15	0	0	1	2	2	2	0	0	0
16	0	0	0	0	0	5	0	1	1
17	0	0	0	1/6	2	2	2	1	1
18	0	0	0	5	3	2	0	0	4
19	0	0	1	3	0	1	1	1	2
20	0	2	0	1	4	1	1	1	0
21	0	0	1	2	2	4	0	0	0
22	1	0	0	1	2/6	1	0	0	1
23	0	0	0	2	3	1/6	0	2	0
24	0	0	1	1/6	2	1	1	0	1

Note: All errors are out of a possible eight chances unless specified.

Number of false alarms for grade 8 children

Subject #	P	PS	PF	R	RS	RF	H	HS	HF
1	0	1/5	0	0	0	0	0	2/4	0
2	0	0	0	0	1	1	0	0	0
3	0	1	1	0	0	0	0	0	0
4	0	0	0	0	0	0	1	0	1
5	0	2	0	0	2	2	0	1	1
6	0	0	1	0	0	1	0	0	0
7	0	0	0	0	0	0	0	1	3
8	1	1	1	0	2	1	0	0	1
9	0	1	0	0	1	1	0	0	0
10	0	0	0	0	0	0	0	0	1
11	0	0	0	0	0	1	0	2	0
12	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	1	1	0
14	0	1	1	0	0	0	2	0	0
15	0	1	0	0	0	1	1	0	0
16	0	0	0	0	0	0	0	0	0
17	0	1	2	0	0	0	0	1	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	1	0	1	1	0
20	0	4	0	1	0	1	0	0	1
21	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	1	0	0
23	0	2	2	0	0	0	0	0	0
24	0	1	0	0	0	0	0	0	0

Note: All errors are out of a possible 7 chances unless specified.

Appendix H

Analysis of variance

picture task reaction time

ANALYSIS OF VARIANCE

PICTURE TASK RT

SOURCE	SS	df	MS	F
GRADE (G)	441.87	2	220.94	41.74*
ERROR	365.19	69	5.29	
SUPPRESSION (S)	8.08	2	4.04	2.92
S X G	4.31	4	1.07	0.78
ERROR	191.06	138	1.38	

*$p < .05$

Appendix I

Analysis of variance

picture task combined errors

ANALYSIS OF VARIANCE

PICTURE TASK COMBINED ERRORS

SOURCE	SS	df	MS	F
GRADE (G)	.007	2	.004	0.81
ERROR	.311	69	.005	
SUPPRESSION (S)	.051	2	.026	7.53*
G X S	.017	4	.004	1.22
ERROR	.471	138	.003	

*$p < .05$

Appendix J

Analysis of variance

picture task miss errors

ANALYSIS OF VARIANCE

PICTURE TASK MISS ERRORS

SOURCE	SS	df	MS	F
GRADE (G)	.012	2	.006	.96
ERROR	.433	69	.009	
SUPPRESSION (S)	.177	2	.088	1.10
G X S	.025	4	.006	1.05
ERROR	.837	138	.006	

*p< .05

Appendix K

Analysis of variance

picture task false alarm errors

ANALYSIS OF VARIANCE

PICTURE TASK FALSE ALARM ERRORS

SOURCE	SS	df	MS	F
GRADE (G)	.012	2	.006	.68
ERROR	.616	69	.009	
SUPPRESSION (S)	.177	2	.088	14.15*
G X S	.016	4	.004	.64
ERROR	.863	138	.006	

*p< .05

Appendix L

Analysis of variance

rhyme task reaction time

ANALYSIS OF VARIANCE

RHYME TASK RT

SOURCE	SS	df	MS	F
GRADE (G)	2240.40	2	1120.20	27.40*
ERROR	2820.80	69	40.88	
SUPPRESSION (S)	119.10	2	59.55	11.40*
S x G	43.86	4	10.97	2.10
ERROR	720.59	138	5.22	

*$p < .05$

Appendix M

Analysis of variance

rhyme task combined errors

ANALYSIS OF VARIANCE

RHYME TASK COMBINED ERRORS

SOURCE	SS	df	MS	F
GRADE (G)	.877	2	.439	16.14*
ERROR	1.875	69	.027	
SUPPRESSION (S)	.151	2	.075	5.85*
G x S	.005	4	.001	.10
ERROR	1.776	138	.013	

*$p < .05$

Appendix N

Analysis of variance

rhyme task miss errors

ANALYSIS OF VARIANCE

RHYME TASK MISS ERRORS

SOURCE	*SS*	*df*	*MS*	*F*
GRADE (G)	.805	2	.402	9.21*
ERROR	3.017	69	.044	
SUPPRESSION (S)	.310	2	.155	5.06*
G X S	.112	4	.028	.92
ERROR	4.228	138	.031	

*$p < .05$

Appendix O

Analysis of variance

rhyme task false alarm errors

ANALYSIS OF VARIANCE

RHYME TASK FALSE ALARM ERRORS

SOURCE	SS	df	MS	F
GRADE (G)	1.133	2	.566	8.58*
ERROR	4.554	69	.066	
SUPPRESSION (S)	.045	2	.023	1.58
G X S	.014	4	.003	.25
ERROR	1.982	138	.014	

*p< .05

Appendix P

Analysis of variance

homophony task reaction time

ANALYSIS OF VARIANCE

HOMOPHONY TASK RT

SOURCE	SS	df	MS	F
GRADE (G)	1067.73	2	533.86	46.68*
ERROR	741.50	69	10.75	
SUPPRESSION (S)	97.57	2	48.79	13.83*
G X S	87.90	4	21.97	6.23*
ERROR	486.74	138	3.53	

*$p < .05$

Appendix Q

Analysis of variance

homophony task combined errors

ANALYSIS OF VARIANCE

HOMOPHONY TASK: COMBINED ERRORS

SOURCE	SS	df	MS	F
GRADE (G)	.330	2	.165	9.58*
ERROR	1.188	69	.017	
SUPPRESSION (S)	.022	2	.011	1.66
G X S	.030	4	.008	1.13
ERROR	.922	138	.007	

*$p < .05$

Appendix R

Analysis of variance

homophony task miss errors

ANALYSIS OF VARIANCE

HOMOPHONY TASK MISS ERRORS

SOURCE	SS	df	MS	F
GRADE (G)	.386	2	.193	7.76*
ERROR	1.713	69	.025	
SUPPRESSION (S)	.056	2	.028	2.45
G x S	.025	4	.006	.54
ERROR	1.583	138	.011	

*$p < .05$

Appendix 5

Analysis of variance

Homophony task false alarm errors

ANALYSIS OF VARIANCE

HOMOPHONY TASK FALSE ALARM ERRORS

SOURCE	SS	df	MS	F
GRADE (G)	.269	2	.135	4.81*
ERROR	1.932	69	.028	
SUPPRESSION (S)	.002	2	.001	.07
G X S	.070	4	.018	1.37
ERROR	1.774	138	.013	

*p· .05