

depth to which it is processed"

(Craik & Lockheart, 1972, p.675-6).

Stimuli may be retained at a particular level of processing by the focusing of attention on the aspects of the stimuli relevant at that level of processing.

"When attention is diverted from the item, information will be lost at the rate appropriate to its level of processing - slower rates for deeper levels"

(ibid., p.676).

The model is relevant to reading research in that the reading process involves a memory component. Moreover, in terms of the present research, it is apparent from the model that different stimuli (e.g. visual/verbal and auditory) may be processed simultaneously provided that they either require different levels of processing, or do not exceed the attention capacity available at a particular processing level.

To summarize, models of attention and related research relevant to the present study were presented in this Section. Broadbent's (1958) "filter" model proposed that all incoming stimuli are initially analyzed physically, after which selective attention acts as a "filter" blocking out some information channels and letting through information from only one channel. Treisman (1964) modified Broadbent's model to include a series of "tests" - the initial test analyzing and "filtering" stimuli on a gross physical level, with tests at later stages analyzing stimuli in terms of content. Norman (1969) proposed that stimuli on all channels imposing on the processing system are analyzed

sufficiently to activate long term memory representation. Selective attention operates at a later stage in information processing. The distinction drawn by Norman between "activation" and "attention" was also discussed. According to Kinsbourne's (1970) model of attention, lateral asymmetry of attention arises when preponderant activity in one cerebral hemisphere "biases" attention to the contralateral side of the body. As related to reading tasks, the model proposes that attention will be biased to the task by the left hemisphere. Craik and Lockheart's (1972) "levels of processing" model was also outlined and related to reading: when two tasks require different levels of processing they may be performed simultaneously.

The preceding theories may be relevant in a discussion of isolated aspects of the reading process (e.g. word recognition and visual feature analysis, memory). However they prove limited in their application to the question of the role of attention in the reading process as a whole, particularly where more complex reading tasks requiring higher levels of cognitive processing are concerned. For example, Broadbent's (1958) "filter" model and Treisman's (1964, Treisman, et al., 1977; Treisman, et al., 1980) modification of this model may be adequate in explaining the role of attention in the physical registration of visual stimuli and the feature analysis stages of word recognition, but they cannot effectively explain the role of attention in tasks where comprehension of printed prose is involved. The role of phonological encoding in such models also remains unclear. It is therefore of value to explore hierarchical models of attention

which attempt to explain the role of attention not only at the physical feature analysis stage in the reading process, but also at higher levels of processing where the concerted working of semantic, memory, and other cognitive systems is considered.

4.2 Hierarchical models of attention

There appears to be some support for a hierarchical view of selective attention in that attention to irrelevant stimuli appears dependent on the complexity of the experimental task to be performed and the complexity of the interfering stimuli, and the level of processing they require. For example, irrelevant light flashes or auditory clicks or cutaneous stimuli, which do not require high levels of cognitive processing, may be "ignored" or "blocked out", particularly when the primary task involves a high processing load or the subject is not highly practised in performing the task (Sabat, 1978). Two hierarchical models of attention will now be discussed, namely those of Martin (1980) and Luria (1973, 1979).

4.2.a Martin's model

Martin (1980), accepting the distinction drawn by Baddeley (1978) between physical and semantic processing, and working largely within a Broadbentian framework, has proposed two stages in cognitive processing. During the first stage all incoming

signals are analyzed on the basis of physical characteristics in a modality-specific fashion and an element of selective attention comes into play on a gross level (e.g. in reading, certain physical features such as the physical shape of a visual stimulus are recorded at a sensory level and attended to while others are not). If the task is sufficiently complex (e.g. involving a sufficiently high information load) the second phase becomes operative, i.e. a "filter" operates to allow some signals through to a limited capacity perceptual processor which initiates semantic analysis of the stimuli, and which, according to Treisman and Davies (1973) is non-modality-specific.

4.2.b Luria's model

According to Luria's (1973) model of attention there are two dimensions ("stages", "phases" or "levels") to attention.

Unit 1 is responsible for maintaining a waking state of cortical tone and a generalized arousal reaction, necessary as a basis for all higher cortical functions.

When a task requiring a high level of cortical processing is performed, the generalized basis of arousal provided by Unit 1 is primed and directed differentially towards the specific features of the stimuli being processed under commands from Unit 3. The directed "attention" stage, corresponding to Kinsbourne's concept of cerebral biasing of attention according to the nature of the task being performed, may have different functions depending on

the nature and complexity of the task in hand. For example, when the task requires distinguishing between primitive shapes such as circles and triangles, attention will be focused at a primary cortical level. This corresponds to Martin's (1980) "first stage" of attention whereby "incoming" stimuli are analyzed on a physical, sensory level and a gross type of selective attention comes into play. When the task requires a higher or "deeper" level of processing, such as a task requiring semantic/lexical decisions, attention will be focused at a tertiary cortical level. This corresponds to Martin's (1980) "second" phase of attention. This correspondence between the models of Martin and Luria must be viewed in broad terms, however, as there is no direct analogue in Martin's model to Luria's concept of secondary cortical processing.

4.3 Attention and the nature of the experimental tasks performed

Studies on attention have employed tasks involving either a single modality (Lansman, 1978; Sachs, 1977; Treisman & Gelade, 1980) or purely perceptual letter or digit discrimination, matching or sorting (Higgins, 1978), or tasks designed specifically to tap the effect of attention on memory tasks (Proctor & Fagnani, 1978), rather than more complex tasks, such as reading, which require higher levels of processing. Nevertheless, the results of such studies may tentatively be applied to the present research, on the grounds that reading requires visual imprinting of stimulus information, and has a

memory component (see Lansman, 1978). Selected studies on attention, relevant to the present research, namely those dealing with divided and/or selective attention will be briefly reviewed.

The nature of divided attention has been investigated by means of dichotic listening tasks in which discrimination between tones or digits or letters or one-syllable words (e.g. Massaro, 1977; Ogden, Martin & Paap, 1980; Yates & Thul, 1979) is required. Other studies have required the simultaneous performance of an auditory (tone pitch) and visual (light duration) discrimination task (Eisler, 1977), or performance of a discrimination task while concurrently counting backwards in 3's (Gardiner & Gregg, 1979; Proctor & Fagnani, 1978) or shadowing a list of digits. In essence, each study has involved the simultaneous performance of two tasks employing either the same modality (both visual or both auditory) or different modalities (one visual, one auditory task). Results of these studies have demonstrated capacity limitations on the amount of information that can be processed in a situation where attention is divided between two tasks (cf. Studies on attention have employed tasks involving either a single modality (Lansman, 1978; Sachs, 1977; Treisman & Gelade, 1980) or purely perceptual letter or digit discrimination, matching or sorting (Higgins, 1978), or tasks designed specifically to tap the effect of attention on memory tasks (Proctor & Fagnani, 1978), rather than more complex tasks, such as reading, which require higher levels of processing. Nevertheless, the results of such studies may tentatively be applied to the present research, on the grounds that reading

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On a purely perceptual level there does appear to be some

evidence for the operation of selective attention processes. For example, Eisler (1977) has proposed that in a task involving time-discrimination where visual and auditory modalities are employed, exclusive attention will be paid to the subjectively more intense modality. However, while selective attention may operate on a gross intermodal level at a purely perceptual or primary recognition stage, Massaro (1977) has shown that intramodally (particularly within the auditory modality) attention cannot be selectively shifted to different aspects of the stimuli (e.g. timbre, pitch, tone). Further support for selective attention at a perceptual level is evident in Broadbent's (1958) "filter" theory of selective attention in which he proposed that certain signals received on one of two or more channels (e.g. dichotic listening tasks or tasks involving two modalities) are selected according to given cues while others are rejected before being fully analyzed. However the limits of selective attention on a perceptual level and the nature of cues effecting such selectivity remain unspecified.

Treisman (1964) applied Broadbent's theory to a more complex verbal task situation with similar result (subjects attended selectively to the primary task while rejecting the irrelevant message, particularly when this was highly dissimilar to the primary task). However, there was evidence that irrelevant stimuli were processed and only rejected at a stage beyond initial perception. Thus selective attention must be operative at a higher cognitive level than merely the perceptual.

Further support for a limit on selective attention processes at higher levels of cognitive processing is to be drawn from the work of Willows (1974) and Willows and MacKinnon (1973). They found that, particularly in the case of skilled readers, irrelevant lines of print, which were presumably selectively ignored as the subjects could not recall them in a free recall-type test, intruded and semantically influenced responses on the primary task, a prose comprehension test.

To summarize, although previous studies of attention have employed tasks involving either a single modality, purely perceptual letter or digit discrimination, or memory tasks, the results of such studies may tentatively be applied to reading research, as reading involves both the visual processing of information and memory. Studies of divided attention have involved the simultaneous performance of two tasks. The results of these studies have demonstrated capacity limitations to the amount of information that may be processed when attention is divided between two tasks, particularly tasks involving the same modality. There is also evidence that while selective attention occurs, these processes are not absolute in blocking out all irrelevant material.

4.4 General summary and implications

The precise role of attention and selective or divided attention in reading has not been clearly defined in the existing

literature. The purpose motivating the present Chapter was to establish to what extent subjects can effectively "block out" irrelevant incoming information while simultaneously performing a primary task (e.g. reading for meaning) and a secondary task (e.g. listening to auditory input). If subjects can "block out" all irrelevant stimuli, and perform efficiently on the reading task under conditions of auditory interference or articulatory suppression, one may conclude that attention is not being biased away from the primary task by the secondary task. If the primary (reading) task is assumed to involve phonological encoding, one may further conclude that the secondary task (auditory input or an articulatory suppression task) does not interfere with the phonological encoding process. The secondary task required for the present study would thus have to be designed so that it would not lead to divided attention but would instead interfere with cognitive processing.

From early "filter" models of attention (Broadbent, 1958; Norman, 1969; Treisman, 1964) and later "hierarchical" models (Luria, 1973, 1979; Martin, 1980), it appears that all incoming stimuli are initially registered and analyzed on the basis of their physical characteristics. Thereafter selective attention operates to allow further processing of certain incoming stimuli. The extent to which incoming stimuli are ignored depends upon the nature of the tasks being performed and the level of processing they require. In terms of Kinsbourne's (1970) model of attention and Craik and Lockheart's (1972) model, different stimuli may be processed simultaneously provided that they either require

different types of processing (e.g. left vs. right hemispheric processing) or different levels of processing, or that they do not exceed the attentional capacity available at a particular processing level. Thus when two tasks are performed at once, it is possible theoretically that the secondary task (e.g. auditory interference or articulatory suppression) will not bias attention away from the primary task (e.g. reading) provided that the two tasks require different types or levels of processing, or, if they require a similar type and level of processing, that the attentional processing capacity available at that level is not exceeded. Experimental studies have verified this argument.

The studies reviewed in this Chapter revealed that there are capacity limitations to the amount of information that can be processed in a situation where two tasks are performed simultaneously. Of particular relevance to the present research is the finding that while selective attention operates to a certain extent at a purely perceptual level, there is evidence that irrelevant stimuli are processed and only rejected at a stage beyond initial sensory registration and analysis of stimuli. Thus it is unlikely that the auditory input used in the present research was "filtered out" at a perceptual level before it could reach the higher levels of cognitive processing at which phonological encoding accompanying reading presumably occurs. Therefore any decrement in performance on the primary task would probably be due to the secondary task's interfering with the cognitive processes involved in the primary task, rather than to a possible division of attention that occurs when two

tasks are performed simultaneously.

ERRATUM: p.84, line 8. After the word "processes" insert:

"which include letter recognition, word recognition, and individual lexical access of words. Coltheart (1978), for example, states that:

"Reading ... is more than lexical access -- even the reading of a single isolated word." (p.213)."

CHAPTER FIVE: A SUMMARY OF THE EXPERIMENTAL TASKS, AIM AND
HYPOTHESES OF THE PRESENT RESEARCH

The importance of the experimental task chosen to investigate the hypothesis of a study has been stressed in the foregoing review of the literature on phonological encoding and reading, and that on attention. Most previous reading research has employed simple tasks tapping isolated aspects of the reading process, assuming the results of such studies could then be generalized to the reading process as a whole. However reading is more than the sum of its constituent processes. Hence the present study has employed reading tasks more representative of complex reading. Moreover, an important concept that has grown out of the research which tested the prelexical/postlexical phonology distinction is that some tasks involve prelexical as opposed to postlexical phonological encoding. The present research aimed at a relatively comprehensive analysis of the role of phonological encoding in reading, and the experimental tasks used were chosen in accordance with the prelexical/postlexical phonological encoding distinction.

Previous studies using tasks involving reading at more complex levels than the on-word level have employed lexical decision tasks using short isolated sentences (Doctor, 1978; Levy, 1975) or short sentences linked thematically (Levy, 1975). The present research employed a complex reading comprehension task designed to tap the processes involved in high level skilled reading. It

is likely that if phonological encoding is used in this task it will be postlexical in nature. It has been argued that a visual lexical access route, where postlexical phonology is employed, is more characteristic of skilled readers than a phonological encoding route using prelexical phonological encoding. Therefore it can be assumed that the skilled readers in this study would employ the faster, possibly more accurate, visual access route, and then use postlexical phonology to assist comprehension of meaning.

Few studies have made use of high level reading tasks such as the reading of complex prose passages, largely because of the difficulty of separating out the various processes involved in such reading tasks (e.g. memory, attention, word recognition). However, the present research aimed at an integrative study of reading, attempting to explain the role of phonological encoding in the context of all these processes involved in complex skilled reading. The problems usually associated with using a complex reading task were regarded as less important than the artificiality of fragmenting the components of the reading process.

It is generally accepted that where phonological encoding is involved in nonword rhyming tasks it will be prelexical/non-lexical in nature, as nonwords are, by definition, not located in the lexicon. Thus a nonword rhyming task was included in the present research to tap prelexical/nonlexical phonological encoding in silent reading. To ensure that the nonwords were in

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fact nonlexical, no subject saw the same nonword twice, as any word or nonword may acquire a place in the lexicon, whether it has a semantic component or not, once it has been seen. Further precautions were taken to ensure that the letter sequences used were legal and regular so that grapheme-phoneme translation could occur. Graphic similarity between nonword pairs was also controlled (Doctor & Coltheart, 1981; Weber, 1970).

The third task used in this study was a modified version of Baron (1977) and Hulme and Ryder Richardson's (1981) Magnitude Judgment task using number pairs printed in either Arabic numerals or English words. Besner and Coltheart (1979) have argued that numbers printed ideographically (i.e. Arabic numerals) are processed by means of different mechanisms to English word numbers. Using a Magnitude Judgment task, they demonstrated that irrelevant variations in the physical numeral size influenced response latency where the numerals were ideographic but not where they were alphabetical. This evidence, coupled with neuropsychological evidence that alexic patients could respond adequately if the numbers were ideographic but not if the numbers were alphabetical, pointed to a difference in processing strategies (hence in underlying mechanisms) employed. According to Baron (1977) if the numbers are Arabic numerals, only a visual lexical access route may be used. If the numbers are printed alphabetically, either an indirect lexical access route using prelexical phonological encoding or a direct visual route may be used. Where the visual lexical access route is used, any phonological encoding (possibly used to check when the visual

length of the word conflicts with the numerical magnitude of the word e.g. SIX THREE) will be postlexical. It is likely that skilled readers used this visual lexical access route with postlexical phonology where the task warranted it, as the task stressed speed as well as accuracy, and the visual access route is faster than the indirect phonological encoding route. In support of this, Hulme and Ryder Richardson (1981) showed that an irrelevant articulatory suppression task (repeatedly reciting the alphabet as quickly as possible) did not interfere differentially with the performance of subjects on the task involving Arabic numerals as opposed to that involving English word numbers. They concluded that:

"although alphabetic and numeral representations of numbers may be processed differently there is no evidence to support the idea that reading alphabetic numbers involves phonological encoding prior to lexical access"
(Hulme & Ryder Richardson, 1981, p.121).

Postlexical phonological encoding may be used, although the task may be simple enough to allow the use of only a visual code. (Vallar & Baddeley, 1982, have suggested that:

"some form of maintenance rehearsal within the visual store is possible, provided the subject is not required to perform a demanding cognitive task at the same time" -
p.58).

The possibility that an indirect lexical access route, where phonology employed is prelexical, still exists in the Magnitude Judgment task used in this research, in that only word numbers with regular grapheme-phoneme correspondences were used. (Words with irregular grapheme-phoneme correspondences would necessitate the use of a visual access route and postlexical phonology).

Other studies using English word numbers have failed to make this distinction between word numbers with regular grapheme-phoneme correspondences and those with irregular correspondences.

It has frequently been asserted in the literature that developmental dyslexics rely too heavily on either a visual or a phonological encoding lexical access strategy while reading. However few studies have investigated dyslexics' use of either strategy. Hulme (1981) has suggested that the Magnitude Judgment task described above may be used to advantage in the study of dyslexia. In particular, he proposed that:

"If retarded readers do rely more on a visual memory code than do normals for remembering such materials, their recall profiles might reveal a distinctive pattern of confusion errors based on visual similarity"
(Hulme, 1981, p.157).

Experiment 4 was designed to assess the effect of prose auditory interference on the dyslexics' performance of the task.

To summarize, three reading tasks were used in the present research, namely:

- i) prose comprehension (EXPERIMENT 1) to tap postlexical phonological encoding,
- ii) nonword rhyming (EXPERIMENT 2) to tap prelexical phonological encoding, and
- iii) magnitude judgment (EXPERIMENTS 3 & 4) to tap the use of both a visual lexical access route (Arabic numerals) and (postlexical) phonological encoding (English

"word" numbers.

5.1 Aim

The aim of the present research was to determine whether auditory input and an articulatory suppression task interferes with silent reading for meaning, and a Magnitude Judgment task, and where an interference effect occurred, to determine its nature. Specifically, the silent reading process was investigated by means of interfering with tasks observing the prelexical/post-lexical phonological encoding distinction, using nonverbal auditory input (music, white sound) and linguistic input at three levels of approximation to English.

5.2 Hypotheses

1. (EXPERIMENT 1) The effect on reading comprehension of auditory interference at a high level of approximation to English will not differ from the effect of auditory interference at a lower level of approximation to English or from the effect of auditory interference which is nonverbal in nature, and the effect of articulatory suppression in terms of latency or accuracy.
2. (EXPERIMENT 2) The effect on the reading of rhyming and nonrhyming nonwords of verbal auditory input at any level of

approximation to English will not differ from the effect of nonverbal auditory input or from the effect of articulatory suppression in terms of latency or accuracy.

3. (EXPERIMENT 3) Prose auditory interference and an articulatory suppression task will not interfere differentially in terms of latency or accuracy, with a magnitude judgment task where the numbers used are Arabic numerals as opposed to where they are English "word" numbers.

4. (EXPERIMENT 4) There will be no difference in performance on the magnitude judgment task in terms of latency or accuracy:

- i) between skilled readers and dyslexics,
- ii) in either group where the numbers used are Arabic numerals as opposed to English "word" numbers,
- iii) in the presence of prose auditory interference as opposed to performance in the absence of auditory interference.

CHAPTER SIX: AUDITORY INTERFERENCE AND PHONOLOGICAL ENCODING IN READING - THE EXPERIMENTS

The first experiment was carried out in order to ascertain whether the simultaneous presence of auditory material or the performance of an articulatory suppression task interfere with the processing of text presented visually during a reading comprehension task. If the "interfering" stimuli and the reading task engage a common underlying process, then a decrement in accuracy and latency of reading may be expected.

EXPERIMENT 1

Method

Subjects

The subjects were thirty male and thirty female undergraduate students at the University of the Witwatersrand who had volunteered for the experiment and who were paid for participating in the study. They all had English as their home language. They had normal hearing, and normal or corrected vision.

Materials

i) Visual stimuli The stimuli which were to be presented visually consisted of white cards (20 cm x 20 cm), one of which had an uppercase X printed in the upper left corner in black Letraset (36 pt. Futura Bold, 9.3 mm). This served as a fixation point which was presented to each subject before the start of every trial. The other two cards each bore one of the two prose comprehension test passages. These passages were taken from the College level of John's (1981) Advanced Reading Inventory - Grade Seven through College, and were typed onto the cards.

Five multiple-choice questions and five open-ended questions were selected from the questions which accompany the chosen prose passages in the Advanced Reading Inventory. The selected questions were then organized into two questionnaires, one for each of the passages.

The visual materials were presented to the subjects by means of a modified two-field Gerbrands Co. Harvard Tachistoscope (Model STD). The fixation X was displayed in the first field and each prose passage in the second field.

ii) Auditory stimuli Five levels of auditory interference were presented:

1) white noise, generated by a Grason-Stadler Noise Generator (Model 455c);

2) music - a recording of Mozart's "Eine Kleine Nachtmusik" by the Columbia Sinfonie-Orchester directed by Bruno Walter (CBS 61 280);

3) prose at the first level of approximation to English, in accordance with Miller and Selfridge's (1950) criteria. A list of words was randomly selected from Kučera and Francis' (1967) word frequency list (frequency #8) and was recorded onto a tape at one second intervals. The list consisted of 291 words (see Appendix C, p.173), and was repeated in seven minute cycles;

4) prose at the fourth level of approximation to English according to the criteria of Miller and Selfridge. This was generated by five volunteer assistants, who created sentences independently of each other. The first person made a sentence using four given words, in the order in which they were presented to her. The first word in this word set was then eliminated and the three remaining words, together with the word used by the sentence generator immediately after the original word set, were passed on to the next sentence generator. This procedure was repeated until a sufficient sample of prose at level IV was obtained (see Appendix C, p.172). This was then read onto a tape and repeated in 110 second cycles;

5. a passage of prose consisting of the final Chapter of July's People (1981) by Nadine Gordimer. The passage was repeated twice to cover the duration of the reading task.

All verbal auditory materials were read onto a tape by a female speaker using standard South African English. For the Level I and Level IV prose, as near normal cadence as was possible was maintained.

During the INTERFERENCE conditions, the auditory stimuli were relayed to the subject through headphones (Murdock D830-V), which were attached to a Wollensak cassette tape recorder (Model 2551 Av). For consistency, headphones were also worn during the NO INPUT conditions.

TABLE 1

Summary of the experimental conditions^a in Experiments 1 and 2

No input ^b	-	white noise ^c
No input	-	music ^d
No input	-	level I
No input	-	level IV
No input	-	prose
No input	-	articulation

a Conditions are independent.

b Scores obtained in the absence of interference input were used as the covariate in the analysis of covariance.

c Scores obtained on the experimental tasks in the presence of white noise, music, level I, level IV, prose or articulation interference constituted the dependent variable.

d "Level" is the level of approximation to English of the verbal auditory input, determined according to Miller and Selfridge's (1950) criteria.

Design

The experimental conditions were embedded within a pretest-posttest within-subjects design (Huck & McLean, 1975) as shown in Table 1. This design was evaluated by means of a oneway analysis of covariance, with the pretest condition (NO INPUT) acting as the covariate.

Procedure

The subjects were randomly assigned to one of the six experimental conditions outlined in Table 1, with five males and five females participating under each condition. Subjects in the first condition received no auditory input while reading one of the prose passages, and heard white noise while reading the other; subjects in the second condition received no auditory input while reading one passage, and heard music while they read the other; subjects in the third condition received no auditory input while reading one passage, and heard the random word list (Level I) while reading the other; subjects in the fourth condition received no auditory input while reading one passage, and heard prose at the fourth level of approximation to English while reading the other; subjects in the fifth condition received no auditory input while reading one passage, and heard the prose piece while reading the other passage, and subjects in the sixth condition had no interference input while reading one passage and performed an articulatory suppression task by

repeating "bla, bla, bla" out loud while reading the other passage. (All subjects participating under this condition had practised repeating "bla bla bla" for a few minutes before the test session began). All the subjects were instructed to concentrate on the prose they were reading silently, and not on the auditory material or the articulatory suppression task. The order in which the AUDITORY INTERFERENCE condition and the NO INPUT condition were presented was pseudo-random, so that for each level of auditory interference half the subjects received no aural input while reading the first passage, and one of the levels of auditory interference while reading the second passage, while the other subjects received one of the levels of interference while reading the first passage and no aural input while reading the second passage. The articulatory suppression task and NO INPUT condition were presented in a similar pseudo-random fashion.

Each subject was tested individually. The subject was seated in front of the tachistoscope and was requested to fixate on the black X which appeared in the first field of the tachistoscope. The appearance of the black X indicated the beginning of a new trial. The prose passage was displayed when the subject pressed a button on a panel in front of him. This button also activated a digital millisecond timer. After the subject had finished reading the passage he released the button, and this stopped the timer. The subject then responded to the questionnaire appropriate to the passage read, and was not timed while answering these questions. The procedure was repeated using the

alternate prose passage and the alternate NO INPUT/INTERFERENCE condition. (The actual instructions given to the subject are shown in Appendix A, p.162).

Results

The latency and the error data were subjected to separate analyses of covariance in which the NO INPUT trials constituted the covariate. The results of the analyses are shown in Tables 2 and 3.

The INTERFERENCE CONDITION main effect for the error data was not significant ($p > 0.05$).

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TABLE 2

Summary of the oneway analysis of covariance performed on the error data^a of the Prose Comprehension test

Source of variation	Sum of squares	Mean squares	df	F
NO INPUT condition ^b	1.364	1.364	1	0.499
INTERFERENCE CONDITION main effect ^c	16.689	3.338	5	1.222
Explained	18.053	3.009	6	1.101
Residual	144.797	2.732	53	-
Total	162.850	2.760	59	-

a The dependent variable in the ANCOVA was the total number of incorrect responses given by the subject on the prose comprehension question set under the INTERFERENCE condition.

b The covariate in the ANCOVA was the total number of errors scored by the subject under the NO INPUT condition.

c The INTERFERENCE CONDITION main effect was non-significant ($p > 0.05$).

The analysis of the latency data showed a significant CONDITION main effect ($F(5,53) = 2.340, p < 0.05$).

TABLE 3

Summary of the oneway analysis of covariance performed on the latency data^a of the Prose Comprehension test

Source of variation	Sum of squares	Mean square	df	F
NO INPUT condition ^b	14 166.445	14 166.445	1	43.002
INTERFERENCE CONDITION main effect	3 854.157	770.831	5	2.340*
Explained	18 020.602	3 003.430	6	9.117
Residual	17 460.348	329.440	53	-
Total	35 480.949	601.372	59	-

* significant ($p < 0.05$).

a The dependent variable in the ANCOVA was the total time, expressed in seconds, taken by the subject to read through each prose passage once.

b The covariate in the ANCOVA was the total time, expressed in seconds, taken by the subject to read the prose passage in the NO INPUT condition.

The adjusted mean latencies for interference condition groups and the results of post hoc t-tests (Edwards, 1968) performed on these adjusted means are shown in Tables 4 and 5 respectively.

TABLE 4

Summary of the latency^a data of the Prose Comprehension test

Condition	Mean Score	Standard Deviation	Adjusted Mean Score
White noise	73.03555	11.0233	59.7755
Music	77.9454	21.0899	74.8954
Level I approximation to English	82.8786	14.8892	80.6086
Level IV approximation to English	96.2245	39.8353	109.3145
Prose	93.5741	26.3798	98.4141
Articulation	80.4431	20.3457	81.0931

^a All latency scores are expressed in seconds.

There was no significant difference ($p > 0.005$) between the effect which Level IV approximation to English had on reading speed as compared with the effect of prose interference on reading speed. The effect of prose interference on reading speed differed significantly ($p < 0.025$) from the effect which any other type of auditory interference had on reading speed. Similarly the effect which level IV approximation to English had on reading speed differed significantly ($p < 0.005$) from the effects white noise, music, level I approximation to English and articulation had on reading speed. White noise differed significantly ($p < 0.025$) in its effect on reading speed from level I approximation to English and from articulation.

TABLE 5

Summary of the results of post hoc t-tests performed on the adjusted latency mean scores^a for Conditions on the Prose Comprehension test

Groups compared	Difference between adjusted means	t
white sound with music	15.1199	1.855
white sound with level I ^b	20.8331	2.556*
white sound with level IV ^b	49.720	6.078**
white sound with prose	36.75	4.741**
white sound with articulation	21.1	2.612*
music with level I	5.7332	0.703
music with level IV	34.4291	4.224**
music with prose	23.5487	2.889**
music with articulation	6.1877	0.759
level I with level IV	28.6959	3.521**
level I with prose	17.8055	2.185*
level I with articulation	0.4545	0.056
level IV with prose	10.8804	1.335
level IV with articulation	28.2214	3.463**
prose with articulation	17.321	2.125*

df = 53

* significant ($p < 0.025$).

** significant ($p < 0.005$).

a Latency mean scores are expressed in seconds.

b "Levels I and IV" are levels I and IV approximation to English, according to Miller and Selfridge's (1950) criteria.

There were no significant differences between the effect on latency of white noise vs. music; music vs. level I approximation to English; and articulation vs. music or level I approximation to English.

Discussion

These results indicate that if the interfering auditory material is syntactically and semantically complex (prose and level IV approximation to English), it interferes with the speed at which English prose can be read silently. This is in agreement with Mowbray's (1953) finding that subject's performance on a prose reading task was poorer when they performed the task while interfering prose was relayed to them by means of a loudspeaker than when they performed the task in the absence of interference. However, Mowbray did not distinguish between speed of reading and accuracy. The present research revealed that while reading was slower where the interfering auditory material was syntactically and semantically complex, accuracy was not adversely affected.

Verbal auditory material which was not syntactically or semantically complex (random words) also interfered with the speed of reading in comparison with nonverbal auditory material (white noise). This result is in keeping with the findings of previous studies (Hintzman, 1965; Murray, 1965) that have revealed no effect of white noise on reading. However, this result is in conflict with results of a study by Baddeley et al. (1981). They found that "unattended speech" in the form of 15 single syllable words read repeatedly onto a tape and relayed to the subject as auditory interference did not interfere with a task requiring the detection of anomalous words and errors of word order in a written prose passage. From this it appears that auditory input in the form of random words interferes with the

TABLE 12

Mean chronological and reading ages^a of the subjects who participated in Experiment 4

Group	Mean age	
	Chronological	Reading
Normal	7.9	9.3
Dyslexic	13.4	9.8

^a All ages are given in years.

relayed to the subject by means of a Sony Walkman Stereo cassette tape recorder (Model WM 1), with headphones attached. Headphones were worn under both NO INPUT and AUDITORY INTERFERENCE conditions.

Design

The experimental conditions were embedded within a pretest-posttest within-subjects design (Huck & McLean, 1975) as shown in Table 13. This design was evaluated by means of a three factor (reading group x interference condition x numerals) analysis of variance. There were repeated measures on the NUMERAL factor (Arabic numbers/English word numbers) and on the CONDITION factor (Prosa/No input).

reading of complex prose only when the words themselves are more complex than single syllables (as in the present study) and are not repeated so frequently as to become familiar enough to be readily ignored. Random word auditory input will also interfere with the reading of complex prose when the reading task requires the use of postlexical phonological encoding in comprehending and remembering the passage and not when the task merely requires error detection. The latter task requires a type of mechanical "proof reading" which must be distinguished from the strategies used in the comprehension of a passage.

It was also shown that the effects of articulatory suppression on reading latency differed from those of white noise. This difference in effect on latency may be due to the more distracting nature of the articulatory suppression task as compared with white noise. Whereas the white noise could be "blocked out" and ignored relatively easily, the subjects found the articulatory suppression task tiring and distracting in that they had to concentrate relatively hard to maintain the repetition of "bla" and not let it deteriorate into dysarthric mumbling. This "distraction" effect probably falsely inflated the difference in effect on reading speed between white noise and articulatory suppression because white noise is a low level form of nonverbal auditory interference. Where the auditory input was more complex (music or level I approximation to English), no distraction effect due to articulatory suppression emerged - articulation and music or random words interfered with the silent reading of prose to a similar extent.

While the effect on prose comprehension of articulation was comparable to that of level I approximation to English, the mechanisms underlying the mild suppressive effects of level I approximation to English and articulation may be different. The level I effect may be due to the low redundancy inherent in randomly presented words which was initially distracting. On the other hand, the articulation effects may be due to the oral kinesthetic distress caused by the constant repetition of a single syllable, and observation of subjects did suggest that they were experiencing some degree of oral kinesthetic distress while articulating "bla, bla, bla" repeatedly.

The finding that the articulatory suppression task did not interfere to a great extent with postlexical phonological encoding in skilled silent reading is in support of Coltheart's conclusion that, in general, articulatory suppression does not interfere with phonological encoding in reading. However the present finding is in opposition to Baddeley's (1979) assumption that articulatory suppression interferes with tasks that require a considerable memory load. These results may be explained in terms of the demands of the tasks employed: whereas Baddeley's (1979) sentence task required the recall of words in strict order, the reading comprehension task employed in the present experiment, while it involved considerable semantic processing, did not require the recall of material in a specific order.

The type of reading task performed by the subjects in this experiment was assumed to have involved postlexical phonology.

It is not necessary to gain access to the internal lexicon in order to pronounce a nonword correctly. Nonwords may be pronounced by means of a strategy solving prelexical or nonlexical phonological recoding of graphemes into phonemes by means of the rules of letter-to-sound correspondence (Venezky, 1970; Wijk, 1966). The aim of EXPERIMENT 2 was to ascertain whether auditory interfering material at different levels of linguistic complexity and an articulatory suppression task would interfere with a task of judging whether visually presented nonwords rhyme.

EXPERIMENT 2

Method

Subjects

The same subjects who had participated in the first experiment participated in this experiment, during the same testing session.

Materials

1) Visual stimuli The stimulus cards were constructed by modifying Coltheart's (1980) list of rhyming nonword pairs to exclude all foreign language words (e.g. koffie, auf) and nonwords which had irregular grapheme-phoneme correspondences. The final list consisted of 40 pairs of rhyming

nonwords. Each pair of rhyming nonwords was matched for graphic similarity with a non-rhyming pair of nonwords, according to Weber's (1970) formula. The nonword pairs were divided into four lists, each containing equal numbers of rhyming and non-rhyming nonwords; such that no nonword appeared more than once within a list (see Appendix B, p.170). Each nonword pair was then printed onto a white card (20 cm x 20 cm) in uppercase Letraset letters (36 pt. Futura Bold, 9.3 mm). The nonwords were printed next to each other in the middle of the card, and were separated by a space of 3 cm.

A practice set of cards, consisting of five rhyming and five non-rhyming nonword pairs was constructed in a similar manner.

ii) Auditory stimuli The same levels of auditory interference as were used in Experiment 1 were used in this experiment.

Design

The experimental conditions were embedded within a pretest-posttest within-subjects design (Huck & McLean, 1975) as shown in Table 1 (see p.94). This design was evaluated by means of a oneway analysis of covariance, with the pretest (NO INPUT) condition acting as the covariate.

Procedure

The subjects were assigned to the same groups they had been in for Experiment 1, so that there were again five males and five females participating under each condition. Subjects in the first condition received no aural input while judging one list of nonwords and white noise while judging the other; subjects in the second condition received no input while judging the one list of nonwords, and heard music while they judged the other; subjects in the third condition received no input while judging one list, and Level I approximation to English while judging the other; subjects in the fourth condition received no input while judging one list, and heard prose at the fourth level of approximation to English while judging the other; subjects in the fifth condition received no input while judging one list, and heard the prose passage while judging the other list, and subjects in the sixth condition had no input while judging one list, and performed an articulatory suppression task by repeating "bla bla bla" out loud while judging the other list. All subjects were instructed to concentrate on the nonword rhyming task and not on the auditory material or on the articulation of "bla bla bla". Order of presentation of the types of interference was pseudo-random, so that within each condition, half the subjects had no aural input or kept silent while judging the first list and heard one of the types of interference or performed the articulatory suppression task while judging the second list. The other subjects had no aural input or kept silent while judging the second list and heard one of the types

of interference or repeated "bla bla bla" while judging the first list.

Each subject was tested individually. The subject was seated at the tachistoscope described above (see Experiment 1) and fixated on a black X printed in the centre of a white card which was presented in the first field of the tachistoscope. There were two handkeys located on a panel in front of the subject. One of these handkeys was labelled YES and the subject was instructed to press this handkey if the pair of nonwords rhymed. The other handkey was labelled NO, and the subject was instructed to press this handkey if the pair of nonwords did not rhyme. For half the subjects the handkey marked YES was on their left-hand side and the handkey marked NO was on their right-hand side, and the reverse applied to the remainder of the subjects. In order to automatize the YES/NO responses, ten practice cards with either YES or NO printed on them in uppercase Letraset letters (36 pt. Futura Bold, 9.3 mm) were presented to each subject before the test session began, and he was asked to press the corresponding handkey. The subject was then presented with the deck of practice nonword pairs which were presented in random order. Thereafter the experimental session began. Each trial began with the experimenter pressing a button which simultaneously displayed the first nonword pair and activated the timer. The subject then responded by pressing one of the two handkeys on the panel in front of him. The order of presentation of the nonword pairs and of the sets of cards was randomized, with the restriction that no subject saw the same nonword twice.

(The actual instructions given to the subject are recorded in Appendix B, p.169).

Results

The latency and error data were subjected to separate oneway analyses of covariance in which the NO INPUT trials constituted the covariate.

TABLE 6

Summary of the oneway analysis of covariance performed on the latency data^a of the Nonword Rhyming test

Source of variation	Sum of squares	Mean square	df	F
NO INPUT conditions ^b	0.671	0.671	1	0.600
INTERFERENCE CONDITION main effect ^c	4.102	0.820	5	0.734
Explained	4.773	0.796	6	0.711
Residual	59.280	1.118	53	-
Total	64.053	1.086	59	-

a The dependent variable in the ANCOVA was the total time taken by the subject to score a correct response under the INTERFERENCE condition.

b The covariate in the ANCOVA was the total time taken by the subject to score a correct response under the NO INPUT condition.

c The INTERFERENCE CONDITION main effect was non-significant ($p > 0.05$).

The results of the ANCOVA performed on the latency data, after the application of a sine transformation, are shown in Table 6. There was no significant INTERFERENCE CONDITION main effect ($F(5,53) = 0.734, p > 0.05$).

The error scores were converted to $P(\bar{X})$, a nonparametric measure of performance (McNicol, 1972). In order to ascertain whether or not the subjects were biased towards responding YES during the experiment, all the YES responses (correct and incorrect), were

TABLE 7

Summary of the oneway analysis of covariance performed on the total number of YES responses^a given on the Nonword Rhyming test

Source of variation	Sum of squares	Mean square	df	F
NO INPUT condition ^b	3.577	3.577	1	2.732
INTERFERENCE CONDITION main effect	8.948	1.790	5	1.366
Explained	12.525	2.087	6	1.594
Residual	69.408	1.310	53	-
Total	81.933	1.389	59	-

a The dependent variable in the ANCOVA was the total number of YES responses, correct and incorrect, given by the subject under the INTERFERENCE condition.

b The covariate in the ANCOVA was the total number of YES responses, correct and incorrect, given by the subject under the NO INPUT condition.

ERRATUM: p.111, line 7. Omit "i.e. there was an equal distribution of YES responses across interference conditions" and insert in its place the following:

"i.e. the inequalities in the distribution of YES responses across interference conditions were not significantly different," .

subjected to a oneway ANCOVA. The covariate in this ANCOVA was the total number of YES responses made by the subject under the NO INPUT condition, and this was compared with the total number of YES responses made under the INTERFERENCE conditions. The results of this ANCOVA are shown in Table 7. Because no significant CONDITION main effect was obtained ($F(5,53) = 1.366$, $p > 0.05$), i.e. there was an equal distribution of YES responses across interference conditions, the $P(\bar{A})$ measure could be used.

TABLE 8

Summary of the oneway analysis of covariance performed on the $P(\bar{A})$ scores^a obtained on the Nonword Rhyming test

Source of variation	Sum of squares	Mean square	df	F
NO INPUT conditions ^b	119.492	119.492	1	6.638*
INTERFERENCE CONDITION main effect	81.203	16.241	5	0.902
Explained	200.695	33.449	6	1.858
Residual	954.034	18.001	53	-
Total	1 154.729	19.572	59	-

* significant ($p < 0.01$).

a The dependent variable in the ANCOVA was the $P(\bar{A})$ score obtained by the subject under the INTERFERENCE condition.

b The covariate in the ANCOVA was the $P(\bar{A})$ score obtained by the subject under the NO INPUT condition.

A oneway analysis of covariance was carried out on the $P(\bar{A})$ scores, with scores obtained under NO INPUT conditions acting as the covariate in the ANCOVA. The results of the ANCOVA are shown in Table 8. Error scores did not differ significantly from one another across conditions ($F(5,53) = 0.902, p > 0.05$).

Discussion

The results of this experiment indicated that the cognitive processes involved in judging whether or not nonwords rhyme are not affected, in terms of latency or accuracy, by auditory interference or by articulatory suppression. This finding partly replicates that of Besner, Davies and Daniels (1981) who found that a nonword rhyming task was performed equally quickly under silent and articulatory suppression conditions. However, Besner et al. found a small but significant decrement in accuracy with articulatory suppression, whereas no accuracy decrement was found in the present experiment. This may be due to the more precise statistical procedure used in the present study.

Most reading research involving articulatory suppression and nonword judgment tasks has involved the use of analyses of variance, where the NO INPUT condition is regarded as a separate "control" condition to which a certain number of subjects are assigned. Other studies have employed a design which is, in strict terms, an analysis of covariance design, with each subject acting as his own control, performing the experimental tasks

in the present study, and warrants further use in reading research.

To summarize, the present research revealed that semantically and syntactically complex prose auditory input reduced the speed with which skilled adult readers performed a task requiring the extensive use of postlexical phonological encoding, and involving semantic processing of printed prose. Aurally presented prose also interfered with the performance of dyslexic and normal children on a task requiring less extensive use of postlexical phonological encoding and a small memory load (Magnitude Judgment task). However, prose auditory interference had no effect on the performance of skilled adult readers on the Magnitude Judgment task. From an examination of the errors made by both children and adults on the task, it appears that a visual lexical access route (which is not interfered with by auditory input) was used in reading both English "word" numbers and Arabic digits. The performance decrement shown by the children in the presence of prose auditory input was attributed to the fact that they found the Magnitude Judgment task difficult and any extra task (including listening to prose) would thus be distracting and lead to a performance decrement. No auditory input interfered with the performance of skilled adults on the Nonword-rhyming task which required the use of pre- or nonlexical phonological encoding.

under both NO INPUT and INTERFERENCE conditions. Data in such studies has been analysed by means of repeated measures analyses of variance, with the NO INPUT condition being regarded as one level of the conditions factor. However, as Huck and McLean (1975) have pointed out, this strategy leads to an underestimation of systematic variance. They suggested instead that an analysis of covariance utilizing the NO INPUT condition as a covariate is the analytic technique of choice: partialling out of baseline variation increases the precision of variance estimates.

It may be argued that the nonword rhyming task may be performed by means of a number of strategies, amongst them being: visual strategies employing the rules of English orthography, "analogy" strategies (Baron, 1977, 1979; Marsh, Desberg & Cooper, 1975) involving the comparison of the whole nonword or its parts with known words and then making the decision "rhyme" or "non-rhyme", or the use of grapheme-phoneme translation processes and pre- or nonlexical phonological encoding. While the possibility of the subjects' using either or both of the first two strategies cannot be excluded, it is likely that the third strategy (pre- or nonlexical phonological encoding) would be used in preference to the first two strategies, because this method would lead to the least errors. Even if pre- or nonlexical phonological strategies were not used in this task it can be asserted with some certainty that postlexical strategies were not used. Thus the absence of an INTERFERENCE effect in the present study may also be due to the fact that the interference conditions used only disturb

postlexical phonological encoding while the subjects did not use postlexical phonological encoding to perform the task. There is support for this conclusion from the work of Besner and Davelaar (1982) who suggested that there are at least two phonological codes used in reading. One code is used to access lexical entries and is not interfered with by articulatory suppression tasks. Another is used to "hold" items in short-term memory and is interfered with by articulatory suppression tasks. In terms of the prelexical/postlexical distinction, the first code corresponds to a prelexical phonological encoding strategy while the second roughly parallels postlexical phonological encoding.

In summary, no decrement was found in the performance (accuracy and latency) of subjects on the nonword rhyming task in the presence of interference, whether such interference was verbal or nonverbal auditory input or an articulatory suppression task. These results partly replicated the findings of a study by Besner et al. (1981). The results were explained in terms of the use of the analysis of covariance technique, and the pre- or nonlexical nature and function of the phonological encoding used in the performance of the task.

A potentially useful method for investigating the role of phonological encoding during reading has been the Magnitude Judgment task. It invites the use of both a direct (visual) route of lexical access when the numbers are presented in digit form and an indirect (phonological encoding) lexical access route, when the numbers are presented as words that have regular

grapheme-phoneme correspondences. In EXPERIMENT 3 the effect of prose auditory input and an articulatory suppression task on the performance of skilled readers on the Magnitude Judgment task was assessed.

EXPERIMENT 3

Method

Subjects

The subjects who were assigned to the prose and articulation interference condition groups in Experiments 1 and 2 also participated in Experiment 3. There were thus 20 subjects in all, 5 males and 5 females per condition.

Materials

1) Visual stimuli Two decks of cards were used. The one deck bore only regularly spelt English numbers less than ten (e.g. THREE, FIVE, SIX, SEVEN, NINE) and the other bore the corresponding Arabic numerals. The number pairs were printed onto white cards (14 cm x 9 cm) with Letraset. (Uppercase letters, Helvetica Medium 7.0 mm Haas, L084, were used for the words, while Helvetica Medium 7.0 mm Haas L086 was used for the numbers). The numbers were printed next to each other in the centre of a card, and were separated by a 2 cm space. All

possible combinations of the numbers were used, and this resulted in twenty cards per deck.

ii) Auditory stimuli The prose passage used as auditory input in Experiments 1 and 2 was employed in this experiment.

TABLE 9

Summary of the design of Experiment 3

Condition ^a	Numerals ^b	
	Arabic numbers	English word numbers
No input ^c - prose ^d		
No input - articulation		

a Conditions are independent.

b There are repeated measures on the NUMERALS factor.

c Scores obtained in the absence of interference input were used as the covariate in the analysis of covariance.

d Scores obtained in the presence of prose or articulation interference constituted the dependent variable.

Design

The experimental conditions were embedded within a pretest-posttest within-subjects design (Huck & McLean, 1975) as shown in

Author Christowitz J

Name of thesis Auditory interference and phonological encoding in reading for meaning 1983

PUBLISHER:

University of the Witwatersrand, Johannesburg

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