PHONOLOGICAL AND ORTHOGRAPHIC PROCESSING IN NORMAL READING DEVELOPMENT

by

Sonia Binns, B.A.(Hons)

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To the best of my knowledge, this thesis contains no material which has been accepted for the award of any other higher degree or graduate diploma in any university and to the best of my knowledge and belief this thesis contains no material previously published or written by another person except where due reference is made in the text of this thesis.

Signed:

Sonia Binns

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SECTION A : LITERATURE REVIEW

Abstract

Theories of normal reading development commonly propose that children move through various stages of reading development from using visual cues to developing phonological awareness and learning letter-to-sound correspondences. Current evidence suggests a reciprocal relationship between phonological awareness and reading ability. Dual-route models of word recognition can be interpreted as conceptualising phonological and orthographic decoding as two independent word processing routes. Flexible use of these strategies is considered necessary for successful reading and can be assessed using a phoneme/grapheme deletion task. Several current models assume that working memory plays an important role in reading since poor readers have been found to have poor working memory skills. This may be related to the capacity of working memory which increases during childhood. Studies of reading have often been criticised for studying disrupted forms of reading by using distracter tasks or subjects with neurological damage. To study reading without disruption a correlational approach may be used to identify cognitive processing components closely associated with capacity to read fluently.

Reading or the rapid and efficient integration of information from the printed page is a complex process involving not only visual, cognitive, and auditory processes, but also linguistic and working memory processes. Printed words are distinctive strings of letters representing sound combinations that correspond to individual letters or letter combinations influenced by the word's spelling. The visual appearance (shape, length, and spelling) of a word is orthography and sound (blended letter sounds) is phonology. Normal readers decode words by either orthographical or phonological means. The study of normal reading development examines whether children differ in their reliance on orthographical and phonological cues in word processing at different ages and whether skilled readers are flexible in using either orthographic or phonological processing strategies. In addition, effective reading involves information retention in some store to allow further information integration. This process must apply at least at the letter, word, and sentence level. Hence the role of working memory in the reading process is of prime importance.

The aim of this review is to delineate various theories and models of normal reading processes and development and word recognition models. The dual-route model of word recognition proposes separate phonological and lexical routes to word recognition and these can explain reading successes and failures. The importance of phonological awareness to reading development and mastery will be shown and evidence of flexible reliance on the two decoding strategies outlined. The usefulness of phoneme/grapheme deletion tasks in general literacy development and more specifically in identifying preferred strategy use will be highlighted. Finally, the development of working memory capacity and its role in the ability to successfully perform a phoneme/grapheme deletion task will be considered.

Normal reading development

Children bring a degree of knowledge and skills to the task of learning to read and then develop skills required to change written text into the more familiar spoken form so that the message contained in the text may be accessed. Children establish the correspondences between written words and spoken words by developing skills for decoding the written word in order to find its equivalence in the spoken form, so as to determine the meaning being conveyed (Garton & Pratt, 1989). Within the general progression of skill acquisition from developing some initial understanding of what reading is to mastering the reading process, there is a complex network of skills that develop in different ways for different children. When children start to read they sometimes make errors with letters of the same shape but different orientation, such as “b”, “d”, “p”, “q”. Previously, it was assumed children had difficulty visually discriminating different letters. As Tunmer (1988) pointed out, it is not a visual discrimination problem but rather difficulty with determining what are the salient features in need of attention. Before learning to read, children have learnt to ignore orientation when labelling objects, for example, a chair is always a chair regardless of its orientation. Thus, children need help in learning what features of print they should pay attention to in order to learn rules which enable them to decode it, for example, that orientation is important when decoding letters.

Most children embark on the decoding process by starting to recognise some words encountered frequently, so words recognised and cues used for recognition vary between children. Gough and Hillinger (1980) suggested that children may learn about 40 words using strategies involving visual cues before the system fails due to insufficient visual features to distinguish new words. However, at some stage children exhaust the number of distinctive visual cues they can effectively use and so must develop other strategies for learning words based on letter-sound correspondences. Learning grapheme-phoneme correspondence rules is important for children to become independent and accurate readers able to decode unfamiliar printed words using sound strategies (Garton & Pratt, 1989).

Goswami (1986) showed that children can use sound patterns associated with letter strings when learning to read. She suggested that children were using the complete sound pattern corresponding to the string rather than the individual grapheme-phoneme correspondences contained within the string. Juel, Griffith, and Gough (1986) also state that there are certain types of words in which knowledge of the correspondence rules is not sufficient to decode them so children must develop specific knowledge about the words to assist them in this task. These include words in which more than one option for the correspondence between letters and sounds exists. For example, children need to determine whether the pair of letters "ea" contained in "steak" sound like "stake", "steek" or "stek". In order to establish what sound it represents, children tend to combine knowledge of the possible sounds with clues about what word will fit from the context provided by the rest of the sentence. It has been suggested (Tunmer, 1988) that children should be encouraged to use a combination of strategies to assist them when they encounter new words in print and that children should use their developing knowledge of grapheme-phoneme correspondence rules to extract from the text some sound cues, while using their knowledge of language and the world to find words that match these cues. However, this process cannot develop effectively if children encounter words in isolation, so reading material for children should be contextualised and meaningful.

Evidence for the importance of phonological processes in the development of reading ability comes from studies which have examined the relationship between phonological skills in spoken language and later reading achievement. In many studies, the correlation between sound segmentation skill and later reading achievement has been highly significant (e.g., Bradley & Bryant, 1983; Lundberg, Olofsson, & Wall, 1980; Tunmer, Herriman, & Nesdale, 1988 as cited in Rack, Snowling, & Olson, 1992). Bradley and Bryant (1985 as cited in Rack, Snowling, & Olson, 1992) demonstrated lasting effects of phonological awareness training, provided alphabetic symbols were used. To benefit from phonics instruction, children must have developed some degree of phonological awareness and be capable of accessing individual word sounds. Bryant, Bradley, Maclean, and Crossland (cited in Garton & Pratt, 1989) showed that early experience with rhyme could predict later reading performance.

Most recent models of reading development are stage models (Ehri & Wilce, 1985; Frith, 1985; Marsh, Friedman, Welch, & Desberg, 1981). These models emphasise an initial visual stage of reading which leads to a phonological stage (see Stuart & Coltheart, 1988 for a critique). In the phonological stage of reading development, children acquire knowledge of letter-sound relationships which they can use to determine the pronunciation of printed words. This important developmental skill allows comprehension of words that, although not visually familiar, have familiar spoken forms. For example, Frith (1985) describes an initial logographic phase during which children recognise words based on salient visual and contextual features, followed by an alphabetic phase in which a letter-to-sound translation strategy is used. The final stage is fluent orthographic reading. Frith proposed that children enter the alphabetic phase when they need to acquire alphabetic skills for use in spelling.

Ehri (1987; Ehri & Wilce, 1987) proposed an alternative model of reading development in which phonological processes are important to the development of sight word recognition. Ehri also proposes three phases of reading acquisition: visual cue reading, phonetic cue reading, and phonemic map reading. Visual cue reading corresponds closely to Frith's logographic reading. In the phonetic cue reading phase, children use the phonetic characteristics of words at a fairly basic level to help them access pronunciations and meanings. Ehri and Wilce (1985) showed that once children have some letter-sound knowledge, they are more likely to learn systematic nonwords (GRF for giraffe) than arbitrary nonwords (XBT for giraffe). The letter string GRF does not contain all information needed to assemble a pronunciation but conveys more phonological information than XBT so the pronunciation of "giraffe" can be accessed (or addressed) more easily. The phonetic cue phase of reading begins as soon as children have some letter-sound knowledge and involves phonetic cues ranging from syllables to phonemes. More sophisticated letter-sound knowledge is used in the phonemic map stage; a prerequisite for this stage is the ability to segment speech at the phonemic level. Development is conceptualised as a process of building on and refining earlier skills in Ehri's model so the stages are not as clearly separated as the stages in Frith's model. Ehri argues that phonological principles used for decoding influence the acquisition of rapidly recognisable sight words so the direct route of dual-route theory is a visual route with phonological information leading into lexical memory.

Ehri and Wilce (1985) suggest that when children begin reading, they shift from visual cue processing of words to phonetic cue processing. Phonetic processing involves recognising and remembering associations between letters when spelling words and sounds when pronouncing words. This learning mechanism is purported to explain how children first develop the ability to read single words reliably, rather than using a visually based sight-word learning or sounding out and blending mechanism. Ehri and Wilce (1987) recognise that children use both visual and phonetic cues in the early stages of learning to read words.

Word recognition models

As originally proposed, word recognition involves at least two, potentially independent, processes: a "direct" lexical recognition process for recognising irregular words such as "yacht" and an "indirect" phonological process for sounding out unfamiliar words or nonsense words (Coltheart, 1978). Recently, it has been argued that the distinction between these two processes (or routes) is artificial (Seidenberg & McClelland, 1989; Van Orden, 1987; Van Orden, Pennington, & Stone, 1990). For example, Van Orden

(1987) argued that phonological processes may influence the recognition of irregularly spelled words since although "yacht" is irregular, the "y" and "t" do receive regular (or predictable) pronunciations. Likewise, various nonphonological factors, such as priming by orthographic, syntactic, and semantic contexts, have been shown to influence nonword pronunciation (Rack, Snowling, & Olsen, 1992).

Seidenberg and McClelland (1989) described a "connectionist" model which uses the same system for pronouncing irregular words and nonsense words. The correspondence between the computer model and behavioural data is not particularly strong (Besner, Twilley, McCann, & Seergobin, 1990). However, the model shows, at least in principle, that a single system can replace the dual-route system.

Coltheart, Curtis, Atkins, and Haller (1993) suggest that a dual-route model remains the most tenable model of learning to read and skilled reading as it accounts for more basic facts about reading than can single-route models such as that proposed by Seidenberg and McClelland (1989). According to the dual-route model, phonological (or sublexical) and orthographic (or lexical) decoding are conceptualised as two independent word processing routes (Barron, 1986). The phonological route involves pre-lexical, phonological word representations being assembled according to rules of grapheme-to-phoneme conversion (GPC). GPC is the conversion of single letters (graphemes) or digraphs, such as "sh" and "th", into corresponding single sounds (phonemes). GPC rules are context sensitive (e.g., the vowel sound "a" in "ate" is elongated by "e") and learning to apply them requires awareness of letter names, phonological awareness, and verbal working memory. The lexical route involves directly mapping the visual characteristics of the word onto a lexical, orthographic whole word representation in order to retrieve post-lexical 'addressed' phonology (Barron, 1986). Skilled reading requires flexible use of both routes, since the orthographic route is inefficient in decoding low frequency, unfamiliar and nonsense words without lexicon stored representations whereas the phonological route is inefficient in decoding high frequency, familiar words because of complex GPC rules in English and exception words which violate GPC rules (Pugh, Rexer, & Katz, 1994). Recent research (e.g., Share, 1995) questions the validity of a strict dual route model suggesting that normal readers probably use both processes as appropriate, direct visual access for short or familiar words and the phonological strategy for longer or unfamiliar words (Siegel, Share, & Geva, 1995).

Phonological awareness

Phonological awareness is concerned with awareness of sounds of language which are important for reading. To master reading and writing processes, children must learn correspondences between individual sounds of language, phonemes and letters that represent those sounds, graphemes (Garton & Pratt, 1989). Phonemes are the most basic units of language which combine to form words, however, focusing on them is difficult for children because as Liberman, Cooper, Shankweiler, and Studdert-Kennedy (1976) have shown, although we perceive phonemes they do not exist as separate entities in the flow of speech. Bryant et al. (1987 as cited in Garton & Pratt, 1989) claim that phonological awareness in children develops initially through awareness of rhyme and early experience with nursery rhymes enhances development of phonological awareness.

Children may be able to segment words into phonemes but once they can spell words, the number of letters becomes a more salient cue and so they use this strategy. Essentially they do not have the high degree of control processing required to focus attention on phonemes, which are less salient than letters.

The direction of causality between reading and phonological awareness development has been debated. Read, Yun-Fei, Hong-Yin, and Bao-Qing (1986) concluded that phonological analysis ability depends on alphabetic literacy. However, several studies have shown the opposite, that phonological awareness is necessary for reading development (Lundberg, Frost, & Peterson, 1988; Cunningham, 1990). Stuart (1990) reports a growing consensus that the relationship between phonological awareness and reading development is reciprocal. Phonological awareness contributes to successful reading development, and vice versa. Perfetti, Beck, Bell, and Hughes (1987) found reading ability facilitated deletion gains, which in turn facilitated reading development. This reciprocity requires that several different forms of phonological awareness be distinguished. Morais, Alegria, and Content (1987) proposed three levels of awareness. Firstly, awareness of phonological strings, which precedes and contributes to reading development, is the ability to disregard meaning and attend to form which Morais et al. (1987) suggest is tested by rhyme and alliteration tasks. Phonetic awareness, which may precede literacy skill acquisition, is awareness of speech as a sequence of phonetic segments, the minimal units relevant for perceptual differentiation. Phonemic awareness is the ability to represent speech as a sequence of phonemes (classically speaking, the minimal units relevant for meaning differentiation) and it is likely that experience of alphabetic orthography is necessary for phonemic awareness development.

Flexible use of decoding strategies

Flexible reliance on either orthographic or phonological decoding strategies, depending on factors such as frequency, spelling regularity, type of orthography of words, and reading experience is demonstrated by numerous studies (cited in Pugh et. al. 1994). Evidence of variable reliance on phonological or visual information would challenge single-route reading processing models. Brysbaert and Praet (1992) demonstrated strategic use of phonetic information in a target word recognition task where usefulness of phonological decoding was manipulated. Paap and Noel (1991) found subject's naming times for reading an "all exception" word list were faster than for a "50% exception and 50% regular" list. They assumed that subjects in the former condition bypassed assembled phonology, which would have competed with the lexical route providing incorrect answers, and used addressed phonology. Thus, concluding that the lexical route is automatic and the phonological route is intentional.

The dual-route theory that reading development involves shifting from indirect, phonological strategy use to faster direct, lexical access strategy use, is the basis of the 'developmental by-pass hypothesis' (Pennington, Lefly, & Van Orden, 1987). This states that in later reading development orthographic coding bypasses phonological coding. Doctor and Coltheart (1980) found older subjects approve fewer orthographically incorrect but phonologically correct sentences than younger subjects. However, Pennington et al.'s (1987) findings that phonological skill continues to develop and contribute to reading development in adulthood discredits the 'by-pass hypothesis'. An alternative hypothesis is that skilled reading involves greater flexibility in strategy use. Manis, Custodia, and Szeszulski (1993) observed older skilled readers avoid using phonological decoding strategies on orthographic tasks better than young readers. Condry, McMahon-Rideout, and Levy (1979) found younger children were less flexible in their strategy use.

Flexibility in using orthographic and phonological decoding strategies can be directly assessed in a phoneme/grapheme deletion task. In the first reported usage of a phoneme deletion task, Bruce (1964) asked children to report what word was obtained when the sound /n/ was removed from "snail". Pronunciation of the residual word in a deletion task varies according to whether a phonological strategy is demanded, so the phonological cues of the initial word are referenced, or whether an orthographic strategy is needed, so the remaining spelling is referenced. Phoneme deletion is sensitive to literacy and orthography (Scholes, 1991). Scholes and Willis (1987a) showed that literacy, and not age, facilitates phonemic awareness, reporting that phoneme deletion could not be done by adult illiterates but could be done quite well by third grade children who were successfully learning to read. Scholes and Willis (1987b) found native-English speaking literate university students responded with phonologically correct and orthographically correct (but phonologically incorrect) answers equally often in a phoneme deletion task (e.g., stimuli such as 'thought' with /t/ deleted, results in the phonologically correct response being 'thaw' and the phonologically incorrect but orthographically correct response being 'though').

Speakers' awareness of the phonemic segmentation of speech (phonemic awareness) is enabled by the ability to internally represent speech as writing, particularly, as alphabetic writing (Scholes, 1991). Subjects who are literate but represent language in non-alphabetic forms (e.g. Chinese) show poor ability to do phoneme deletion tasks (Read, Zhang, Nie, & Ding, 1986). Stuart (1990) found that children who are good at reading and spelling used both phonological and orthographic strategies in the deletion task. Children who were not good at reading and spelling were largely incorrect in the deletion task. Where they did perform correctly, they were significantly more likely to accomplish the task by a phonological strategy. Incorrect responses provide additional evidence of phonological strategy use.

Literacy skills play an indirect role in good reader/speller ability to perform deletion tasks by allowing orthographic knowledge use to solve the phonological test question (Bertelson & de Gelder, 1988). The interaction of orthographic strategy use with stimulus lexicality suggests use of the orthographic strategy depends on ability to access a stored orthographic representation. Stuart (1990) found that poor readers/spellers have fewer stored orthographic representations and so cannot use an orthographic strategy. Good readers/spellers were also significantly better than poor readers/spellers at deletion using a phonological strategy. Ability to perform the phoneme deletion task was linked to literacy levels by Bruce (1964). In addition to the literacy requirement for ability to do phoneme deletion there is also a maturational component (Patel & Patterson, 1984 as cited in Scholes, 1991). Baddeley

(1979) also found that poor readers have poor working memory skills. In particular it is thought that the capacity of working memory is smaller in poor readers (Cordoni, O'Donnell, Ramaniah, Kurtz, & Rosenshein, 1981 as cited in Baddeley, 1990).

Working memory

The capacity of verbal working memory increases up to about 11 years of age (Hitch, Halliday, & Littler, 1984 as cited in Baddeley, 1990). Phonological coding use in the store and rehearsal of auditory stimuli in the phonological loop is demonstrated in children as young as four years (Gathercole & Baddeley, 1993). There is no evidence of phonological coding or rehearsal with visual stimuli (pictures, digits, letters) until about eight years of age (Hitch, Halliday, Dodd, & Littler, 1989 as cited in Baddeley, 1990). At about this time children become proficient readers, and demonstrate ability to read silently (Gathercole & Baddeley, 1993).

The term working memory refers to the assumption that some form of temporary information storage is necessary for performing a wide range of more complex information processing skills/cognitive tasks including comprehension, learning, and reasoning (Baddeley, 1986). An important factor in evaluating any model of working memory is its capacity to explain such skills. A successful model should provide a framework for studying cognitive skills in a way that increases understanding of each skill, and also enriches and develops the model of working memory.

Baddeley and Hitch (1974) argued that the concept of a unitary short-term store system was insufficient and instead proposed the multicomponent working memory model which comprises an attentional control system, the central executive, aided by slave systems responsible for temporary storage and manipulation of either visual material (the visuospatial sketchpad), or verbal material (the phonological loop).

The central executive is a limited-capacity system responsible for providing the link between the slave systems and long term memory (LTM), and is responsible for strategy selection and planning (Baddeley, 1995). There is concern (Baddeley, 1992) that the concept of a central executive may reflect nothing more than a convenient homunculus, however, researchers are now attempting to specify and understand the various subcomponents of executive control.

Good evidence appears to exist (Baddeley, 1986) for a temporary visuo-spatial store (visuo-spatial sketchpad), capable of retaining and manipulating images, and susceptible to disruption by concurrent spatial processing. It seems likely that the system has both a visual component, concerned with factors such as colour and shape, and a spatial component concerned with location. Research results suggest a visuo-spatial system, somewhat analogous to the articulatory loop (Baddeley, 1990). Like the loop, the visuo-spatial system can be fed either directly through visual perception or indirectly through visual image generation. An unattended picture effect (Logie, 1986) suggests obligatory access to the store by visual information, similar to the articulatory loop. The system appears to be used in setting up and using visual imagery mnemonics, but does not appear responsible for the imageability effect in long-term verbal memory. Initially, the system appeared spatial rather than visual in character, however, it now seems likely to either represent a multi-faceted system, with both visual and spatial dimensions, or possibly two separate systems.

The articulatory or phonological loop is responsible for maintaining and manipulating speech-based information. It is assumed to consist of two subcomponents: a phonological memory store, which can hold traces of acoustic or speech-based material and a process of articulatory sub-vocal rehearsal (articulatory control process based on inner speech) which maintains traces assumed to fade within about two seconds unless refreshed by this rehearsal process, a conclusion also supported by a recent PET-scanning study (Paulesu, Frith, & Frackowiak, 1993 as cited in Baddeley, 1995). This serves two useful functions: maintaining the memory trace by subvocal rehearsal and registering visually presented material by subvocal naming. The memory trace can be refreshed by a process of reading off the trace into the articulatory control process which then feeds it back into the store, the process underlying subvocal rehearsal. The articulatory control process is also able to take written material, convert it into a phonological code and register it in the phonological store (Baddeley, 1990). The major phenomena that have led to the formulation of the phonological loop model are the phonological similarity effect, the word-length effect, articulatory suppression, the irrelevant speech effect, and STM patients.

The first convincing evidence of the importance of phonological coding in STM was produced by Conrad (1964) who observed that when subjects attempted to recall strings of visually presented consonants, their errors were acoustically or phonologically similar to the target item, hence B was more likely to be misremembered as V than as visually more similar R. Letters or words that are similar in sound lead to poorer immediate serial recall (Conrad & Hull, 1964) indicating a phonological similarity effect. This is assumed to occur because the phonological store relies purely on a phonological code; similar codes present fewer discriminating features between items, leading to impaired retrieval and poorer recall (Baddeley, 1992). This phonological confusion had presumably occurred in immediate memory, not in perceiving the letter since the letters were visually presented. It was suggested that these effects indicate an acoustically based short term store. Baddeley (1966a) later used words to confirm that similar-sounding items (man, mat, cap, map, can) led to poorer immediate serial recall than phonologically dissimilar words (pit, day, cow, pen, rig), whereas similarity of meaning (huge, big, large, great, tall) caused few problems. However, when long-term learning was required, the pattern was reversed and meaning became the dominant factor (Baddeley, 1966b) with phonological similarity ceasing to be important, a finding extended by Kintsch and Buschke (1969).

Initial studies tended to refer to the phonological similarity effect as acoustic, implying that the crucial factor was sound similarity of items being remembered, suggesting the short term store was acoustically based, while the long term store favoured semantic coding. However, it was subsequently suggested that coding might be articulatory (coding assumed to be based on speech production) rather than acoustic (Hintzman, 1967 as cited in Baddeley, 1986) since there is good evidence short-term memory relies on subvocal rehearsal (Sperling, 1967; Waugh & Norman, 1965; Atkinson & Shriffrin, 1968 as cited in Baddeley, Lewis & Vallar, 1984). More convincing evidence for articulatory coding came from Conrad (1970). Despite never being able to hear, some congenitally deaf children (rated as good speakers by their teachers) showed phonological confusions in remembering consonant sequences. This result suggests articulatory coding, but does not exclude the possibility that normal hearing subjects also code acoustically. The phonological similarity effect appears to be a function of the short-term store which is maintained and refreshed by the process of articulation, and which can be used to feed the articulatory process. This store appears accessible either through auditory presentation or by the articulatory coding of visually presented material.

The principal source of evidence for the importance of articulation in the phonological loop comes from the word length effect, a tendency for memory span to decline as words increase in length. This is assumed to occur because rehearsal occurs in real time, so long words take longer to rehearse, increasing the opportunity for the memory trace to decay before or during recall (Baddeley, Thomson, & Buchanan, 1975; Cowan, 1984 as cited in Baddeley, 1995). Baddeley et al. (1975 as cited in Baddeley, 1995) observed a consistent tendency for subjects to do better at recalling short duration words than long duration words when two sets of words were matched for number of syllables and number of phonemes. A correlation existed between speech rate and memory span indicating that memory span may represent the number of items of whatever length that can be uttered in about two seconds. A subsequent study found that spoken word duration not length in terms of syllables was the crucial variable in memory span since word sequences that tend to have long vowels and be spoken slowly such as “Friday” and “harpoon” lead to somewhat shorter spans than words with the same number of syllables and phonemes that can be spoken more rapidly (e.g., wicket, bishop) (Baddeley, 1990). This is consistent with a trace decay hypothesis suggesting duration is important since longer words take longer to say so the memory trace is refreshed less frequently which leads to more forgetting. If item presentation leaves a memory trace which decays over time then re-presentation of an item either by the experimenter, or by subject rehearsal will refresh the trace and stop the decay process. The amount retained will therefore be a joint function of decay rate and rehearsal rate. With very few items, the subject can rehearse the complete sequence in less time than it takes the memory trace to decay, allowing the sequence to be maintained indefinitely (Vallar & Baddeley, 1982). As the sequence length increases so too does time needed to rehearse the entire sequence, until a point is reached at which decay time for an individual item is less than the time to rehearse the total sequence and this is when errors begin to occur. Thus, it is possible to express memory span in terms of either number of items or total spoken duration. This is more plausible than an interference theory or displacement model which would argue that number of syllables is the crucial factor. Some theorists (see Baddeley, 1986) have argued that one component of STM is a system containing a limited number of slots or memory locations so when the number of items to be remembered exceeds this number, forgetting occurs. If each slot held a fixed number of syllables, then polysyllabic words would overload the system more rapidly than monosyllables.

Evidence of more direct relevance to normal memory is provided by the phenomenon of articulatory suppression. In a series of experiments, Murray (1965 as cited in Baddeley, 1986) varied the strength of overt vocalisation required of the subject, generally finding a greater amount of articulation produced a better performance. When visually presented with a sequence of digits and prevented from subvocal rehearsal by uttering an irrelevant sound, Murray found that performance was significantly poorer. While this effect can be attributed to suppression of articulatory coding, it could also be argued that irrelevant sound articulation merely acted as a general distracter. However, this interpretation does not adequately explain Murray's findings that subjects required to remember visually presented sequences of consonants show no evidence of a phonological similarity effect when required to suppress articulation. Articulatory suppression eliminates the phonological similarity effect with visually presented material (e.g., Levy, 1971; Estes, 1973; Peterson & Johnson, 1971 as cited in Baddeley, 1986). This contrasts with auditory presentation, where the phonological similarity effect withstands suppression. Baddeley et al., (1984) showed consistently that similarity has a marked effect whether suppression is at input only or at both input and recall with auditorily presented material. Suppression interferes with the subvocal naming process whereby visual information is registered in the phonological store. Thus articulatory suppression eliminates the phonological similarity effect for visually presented material, but not when presentation is auditory, as this guarantees access to the phonological store without need for subvocal naming (Baddeley, 1995).

Articulatory suppression eliminates the word length effect whether presentation is auditory or visual, presumably because it prevents rehearsal. The word length effect depends on the subvocal rehearsal rate so if subvocal rehearsal is prevented, then word length is no longer relevant to performance (Baddeley et al., 1984). Since the word length effect is assumed to reflect the articulation process per se, then preventing articulation should abolish the effect, regardless of presentation modality. However, this occurs only when suppression is prevented during both input and recall. Interestingly, when long and short words are presented visually, suppression during input is sufficient to remove the word length effect. This difference between visual and auditory presentation probably reflects the greater compatibility of an articulatory response to auditory material than to visual. It seems likely that part of the language learning process involves an in-built capacity for repeating heard stimuli. This is reflected both in the ease of such responses in adults (Davis, Moray, & Treisman, 1961; McLeod & Posner, 1984 as cited in Baddeley et al., 1984) and the much earlier age at which children rehearse auditorily presented words as opposed to names of visually presented pictures (Hitch & Halliday, 1983 as cited in Baddeley et al., 1984).

Available evidence suggests that phonological similarity and word length effects reflect different components of the articulatory loop system (Baddeley, 1986). The word length effect appears to reflect the process of articulatory rehearsal, because longer words take longer to say and thereby reduces the rate at which an item can be rehearsed. Articulatory suppression appears to be sufficient to stop the process of rehearsal and so remove the word length effect.

With visual presentation, patients with short-term memory deficits typically do not show either phonological similarity or word length effects (Vallar & Baddeley, 1984; Vallar & Shallice, 1990 as cited in Baddeley, 1992). These patients are assumed to have a defective phonological store so they gain no benefit from attempting to phonologically store visually presented items, which are better recalled on the basis of other codes.

The presentation of irrelevant spoken material also disrupts immediate serial recall. The disrupting effect is independent of the meaning of the irrelevant material, being as great when in a foreign language as when in the subject's native language. The disrupting material must be speech-like since white noise has no effect and non-vocal music produces a level of disruption in-between that of noise and speech whereas sound intensity is not an important variable (Colle & Welsh, 1976; Salame & Baddeley, 1982; 1989 as cited in Baddeley, 1992). It is assumed that irrelevant speech accesses the phonological store and corrupts the memory trace, leading to impaired recall (Baddeley, 1992).

Baddeley, Papagno, and Vallar (1988 as cited in Baddeley, 1992) studied a patient with a very pure phonological memory deficit, finding that she performed normally at standard paired associate learning but performed very badly at new phonological learning. Later studies attempted simulation using articulatory suppression with normal subjects, showing that paired associate learning is unaffected by suppression whereas foreign language vocabulary learning is clearly impaired (Papagno, Valentine, & Baddeley, 1991 as cited in Baddeley, 1992).

A number of current models (e.g., Just & Carpenter, 1980; Kintsch & van Dijk, 1978 as cited in Baddeley, 1986) assume working memory plays an important role in reading, and have been tested by Glanzer and his colleagues. Glanzer, Dorfman, and Kaplan (1981) showed that interposing a filler task between successive sentences of prose led to slower reading of the sentence that followed the break, although no effect was detected on comprehension accuracy. There does appear to be good evidence for general working memory involvement in fluent reading comprehension (Baddeley, 1986).

Summary and conclusions

Most approaches to the study of fluent reading have attempted to break down performance in some way, either by presenting stimuli very briefly, by accompanying reading by some distracting secondary task, or by taking advantage of the disruption of reading that sometimes occurs following brain damage. These may be valuable ways of gaining insight into the process of fluent reading, but are criticised for studying an impaired or disrupted form of reading which may not give results directly applicable to fluent reading. One possible way of studying reading without disruption is to take advantage of the individual differences that occur in reading ability across subjects. Subjects are given a range of tasks, and a correlational approach used to identify which components of cognitive processing appear to be associated most closely with capacity to read fluently. Using this approach, Daneman and Carpenter (1980 as cited in Baddeley, 1986) attempted to test the hypothesis that reading depends on general working memory. Earlier studies (e.g., Perfetti & Lesgold, 1977 as cited in Baddeley, 1986) used standard digit span measures as a measure of working memory, and found only a weak relationship between digit span and reading skill.

Daneman and Carpenter (1980 as cited in Baddeley, 1986) developed a measure of working memory capacity based on a task that required the subject to read a series of sentences and subsequently recall the last word of each. The need to simultaneously comprehend and remember made this different from a simple word span task. They found a robust correlation between working memory span measure and performance on standard tests of reading comprehension. In a subsequent study, Daneman and Carpenter (1983) found subjects with a low working memory span were more likely to be misled by inappropriate context than subjects with a high working memory span. Studies by Oakhill, Yuill, and Parkin (1988 as cited in Baddeley, 1995) were concerned with children who were good readers in that they were able to pronounce printed words, but poor comprehenders. They found that such children perform poorly on working memory span tasks and when asked to draw inferences from the text. Kemper (1992 as cited in Baddeley, 1995) studied language comprehension in the elderly and suggested a deterioration in working memory capacity results in difficulties producing or comprehending certain types of syntactic structure.

A feature of memory development in children is the tendency for digit span to increase systematically with age. Nicolson (1981 as cited in Baddeley, 1990) found a clear relationship between the speed at which children of different ages could articulate and their memory span suggesting a tendency for older children to rehearse faster. This finding was replicated and extended by Hulme, Thomson, Muir, and Lawrence (1984 as cited in Baddeley, 1990) and Hitch, Halliday, and Littler (1984 as cited in Baddeley, 1990). Children of various ages were tested for immediate serial recall of items with names of varying lengths. When presentation was auditory, length effected children as young as four. Results suggested that increased age enhances performance simply because subjects articulate more rapidly.

Models of reading processes have attempted to map the development of normal reading resulting in a number of models which assume that children pass through various stages when learning to read. Proponents of these models (e.g., Ehri & Wilce, 1985; Frith, 1985) have emphasised the importance of phonological processes and skill development to enable children to become proficient readers. Other researchers have considered the importance of phonological and other factors when developing models of word recognition. Debate has arisen in this area regarding the efficacy of single-route and dual-route models as explanations of word recognition processes. Theorists now recognise that skilled reading requires the flexible use of both orthographic and phonological processing routes. The relationship between the development of phonological awareness (letter-to-sound correspondences) and reading skill is thought to be reciprocal and successful reading development requires flexible use of both orthographic and phonological decoding strategies. Such flexibility in strategy use can be assessed using a phoneme/grapheme deletion task. Baddeley (1986) reports evidence suggesting the involvement of working memory in reading comprehension and several models have assumed the importance of working memory in reading processes. Previously, studies of fluent reading have considered performance which has been disrupted in some way (e.g., distracter tasks, neurological damage). However, a more direct way to study reading is to use a correlational approach to identify components of cognitive processing that are associated with ability to read fluently. Thus, separate studies have used a variety of tasks with different groups. The opportunity now exists to collate some of this research by exploiting the individual differences in reading ability that occurs in the general population during normal reading development to find which tasks best identify the components of cognitive processing most relevant to the skill of reading.

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PHONOLOGICAL AND ORTHOGRAPHIC STRATEGY

USE IN

NORMAL READING DEVELOPMENT

by

Sonia Binns, B.A.(Hons)

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Abstract

Flexible use of orthographic and phonological processing are necessary for skilled reading. Working memory is also thought to be important in reading development since evidence suggests that the phonological loop plays an important role in learning to read. A phoneme and grapheme deletion task was used to investigate the phonological and orthographic strategy use of children during normal reading development from grade 2 to 10. Working memory tasks were also used to investigate the development of working memory capacity. Strategy choice was manipulated by presenting words orally or visually, and instructing children to address the word's sound (phonology) or spelling (orthography). Younger children were expected to be more successful at using a phonological strategy than an orthographical strategy whereas older children were expected to be flexible and use both strategies successfully. Spelling and reading performance were expected to correlate with phoneme/grapheme deletion task performance. Younger children were expected to have smaller working memory capacities than older children such that digit span would be greater than span for non-rhyming words followed by rhyming word span. Generally, the results supported these hypotheses suggesting that decoding ability improves and working memory capacity increases with age. Grade was more highly correlated with performance on the phoneme/grapheme deletion tasks and spelling/reading performance than with performance on the working memory tasks.

Fundamental differences exist between the skills involved in dealing with print and with speech. The primary linguistic activities of listening and speaking (Mattingly, 1972), which emerge through maturational processes, do not require an explicit awareness of the internal phonological structure of words. However, a metalinguistic awareness that words comprise of syllables and phonemes is needed when language users turn from the primary language activities of speaking and listening to the secondary language activities of reading, versification, and word games (Liberman, 1971; Mattingly, 1972, 1984). The possibility that reading experience plays a particularly important role in the development of phonological awareness arises from the many studies that reveal an association between phonological awareness and success in learning to read an alphabetic orthography. Performance on tasks which require manipulations of phonological structure not only distinguishes good and poor readers in early grades (Alegria, Pignot, & Morais, 1982; Katz, 1982; Liberman, 1973 as cited in Mann, 1986) but also correlates with older children's scores on standard reading tests (Perfetti, 1985; Treiman & Baron, 1983). Present evidence suggests that the relationship between phonological awareness and reading ability is a two-way street (Perfetti, 1985) which may depend on the level of awareness being addressed. Awareness of syllables is not very dependent on reading experience whereas awareness of phonemes may depend upon the experience of learning to read the alphabet and on methods of instruction that draw attention to phonemic structure.

Although there are many theories on development of reading most of these theories allow that children move through various stages of learning to read. Six phases of reading development are assumed to exist (Raison, 1994). Reading development begins with role play reading in which children display reading-like behaviour as they reconstruct stories for themselves. The next phase is experimental reading where children use their memory of familiar texts to match some spoken words and written words. In the early reading phase, children may read unfamiliar texts slowly and deliberately as they focus on reading exactly what is on the page. Children may sometimes comment on and question texts while also beginning to reflect on their own strategies, for example, for working out unknown words. Readers then enter a transitional reading phase where they begin to integrate a variety of reading strategies. Reading then becomes purposeful and automatic in the independent reading phase. Children become aware of the reading strategies they use only when encountering difficult text or reading for a specific purpose. The final phase is advanced reading when readers are able to critically reflect on and respond to text, recognise specific language forms, and are able to select, use, monitor, and reflect on appropriate strategies for different reading purposes amongst other skills.

Most children embark on the decoding process of reading by starting to recognise some frequently encountered words which can be remembered using salient cues. The words recognised and the cues used for recognition will vary from one child to another. Children may learn up to about 40 words using strategies involving visual cues, before this system fails because there are insufficient visual features to distinguish new words (Gough & Hillinger, 1980). Ehri and Wilce (1985) concluded that children make use of relevant phonetic cues (which make use of individual letter sounds) earlier in the reading acquisition process than Gough and Hillinger claimed. Children most probably use a combination of strategies as they shift from relying on visual features to making use of their developing knowledge of grapheme-phoneme correspondences. Ehri and Wilce (1987) recognised that children use both visual and phonetic cues in the early stages of learning to read words.

It has been shown that working memory is important in reading development which is thought to occur in a series of stages and may be affected by the developing capacity of working memory in children. The capacity of verbal working memory increases up to about 11 years of age (Hitch, Halliday, & Littler, 1984 as cited in Baddeley, 1990). Children as young as four years have demonstrated the use of phonological coding in the store and rehearsal of auditory stimuli in the phonological loop (Gathercole & Baddeley, 1993). However, there is no evidence of phonological coding or rehearsal with visual stimuli (pictures, digits, letters) until about eight years of age (Hitch, Halliday, Dodd, & Littler, 1989 as cited in Baddeley, 1990). Children become proficient readers and demonstrate the ability to read silently at about this time (Gathercole & Baddeley, 1993).

Working memory is responsible for temporarily storing and manipulating information in connection with performing other, more complex tasks (Baddeley, 1986). A multicomponent concept of working memory comprises an attentional control system (central executive) aided by slave systems responsible for the temporary storage and manipulation of either visual material (visuo-spatial sketchpad) or verbal material (phonological loop). The central executive is a limited-capacity system responsible for providing the link between the slave systems and long term memory and for strategy selection and planning.

The phonological loop has two components, a memory store capable of holding phonological information for a couple of seconds and an articulatory control process (Baddeley, 1986, 1992). Memory traces may be refreshed by subvocal articulation, a process that can also be used to feed the store, when the subject registers visually presented material by subvocal naming (Baddeley, 1995). The system is assumed to underlie digit span, with the number of items retained being a joint function of the rate at which the memory trace fades and the rate at which it can be refreshed by subvocal rehearsal (Baddeley, 1995). Baddeley, Lewis, and Vallar's (1984) results are consistent with the concept of a loop comprised of a phonological store, responsible for the phonological similarity effect. Conrad (1964) first observed that when subjects recall visually presented sequences of consonants, their errors were phonologically similar to the target item, hence B is more likely to be misremembered as V than the visually similar R. Letters or words that sound similar lead to poorer immediate serial recall (Conrad & Hull, 1964) indicating a phonological similarity effect. This occurs because the phonological store relies purely on a phonological code; similar codes present fewer discriminating features between items, leading to impaired retrieval and poorer recall (Baddeley, 1992). The phonological similarity effect appears to be a function of the short-term store, maintained and refreshed by the process of articulation, and which can be used to feed the articulatory process. This store appears accessible either through auditory presentation or by articulatory coding of visually presented material.

Evidence seems to suggest that the phonological loop plays an important role in learning to read (Jorm, 1983). One of the common features of a group of children selected because they have a specific problem in learning to read, despite normal intelligence and supportive background, is an impaired memory span (Miles & Ellis, 1981 as cited in Baddeley, 1990). Reduced digit span is a prominent feature of children suffering developmental dyslexia (Jorm, 1983; Torgeson & Houck, 1980). They also tend to perform poorly on tasks that do not directly test memory but involve phonological manipulation or require phonological awareness such as phoneme deletion or judging whether words rhyme. Consequently, controversy exists as to whether the deficit underlying normal reading development is one of memory, phonological awareness, or some other common factor (Bradley & Bryant, 1983; Morais, Alegria, &

Content, 1987). Clear evidence exists for a reciprocal relationship between these factors and learning to read, such that learning to read enhances performance on memory span and phonological awareness, which in turn are associated with improvements in reading (Ellis, 1988 as cited in Baddeley, 1990). Morais et al. (1987) have shown that illiterate adults tend to show impaired phonological awareness, and to improve as they learn to read. There is little doubt, then, that in normal reading development these factors interact and it seems likely that phonological deficits are related to the development of the phonological loop system. Baddeley (1992) cites a number of studies which lend support to the view that the phonological loop plays an important role in the early stage of reading and suggests that it is concerned with the acquisition of the association between letters and sounds; a task that Byrne and Fielding-Barnsley (1989) have shown is an important factor in the early stages of acquiring reading. Children can learn to read by more than one route (Campbell & Butterworth, 1985) and while there are many factors involved in reading acquisition, Baddeley (1992) suspects that the usual and most effective method of reading acquisition places a major load on the phonological loop at this critical stage.

Pugh, Rexer, and Katz (1994) cite studies demonstrating flexibility in the degree of dependence on phonological or visual codes by subjects depending on factors such as word frequency, spelling regularity, reading experience, and type of orthography. Pugh et al. (1994) suggest that the very existence of flexibility suggests that both phonological and direct processing are required in everyday reading, and that coding flexibility is highly practiced. Readiness for strategic variation in decoding methods by adult readers suggests that this flexibility is useful for everyday reading. Condry, McMahon-Rideout, and Levy (1979) suggest that looking for a name in a telephone book requires orthographic decoding, poetry reading involves phonetic strategies, and reading a novel requires a semantic decoding strategy. Pugh et al. (1994) suggest that subjects are able to control the extent to which they engage phonological processing in making lexical decisions. Pugh et al. (1994) suggest that the locus of this flexibility is not post-lexical which then poses a problem for single-route reading processing models, in general, which would seem compelled to place coding flexibility at some post-lexical cognitive stage.

Older, skilled readers avoid using phonological decoding strategies on orthographic tasks better than younger readers (Manis, Custodia, & Szeszulski, 1993). Younger children were less flexible in their strategy use, finding it difficult to change from accessing semantic information to accessing phonemic or graphemic information when pairing words (Condry, McMahon-Rideout, & Levy, 1979).

Many studies have manipulated task demands to make phonological coding advantageous or disadvantageous. Davelaar, Coltheart, Besner, and Jonasson (1978) manipulated whether the nonword context contained pseudohomophones (nonwords which sound like real words, e.g., brane and bote) in a lexical decision task and concluded that subjects can strategically control whether they use phonological coding. Using a naming task, Paap and Noel (1991) manipulated context across groups. One group of subjects were asked to pronounce a list of exception words, whereas a second group was given equal numbers of exception and regular words. Subjects who received all exception words were faster on the critical items than subjects in the mixed context. Paap and Noel (1991) claimed that subjects in the all-exception word context bypassed assembled phonology and used addressed phonology to name target words because phonological coding is not efficient for exception words. By relying on direct access, they processed words more quickly than subjects who received a mixed list, since they were presumably engaged in a greater degree of assembled phonological coding. Paap and Noel have argued that this finding is consistent with dual route theory.

The dual-route theory of reading (Coltheart, Davelaar, Jonasson, & Besner, 1977 as cited in Pugh, Rexer & Katz, 1994) posits two routes to pronunciation: a phonologic route and a direct access route. The phonologic route consists of two stages; orthographic representations (letters or clusters of letters) are converted into appropriate phonological representations such as phonemes (assembled phonology) which are then matched to their appropriate lexical entries or articulation (when naming). The direct access route is thought to involve direct mapping from orthographic representations to lexical entries. Specific versions of dual-route theories may differ slightly but all usually include the following assumptions (Pugh et al. 1994). Firstly, the two routes to lexicon, direct and phonologic, operate independently of one another. Secondly, since the phonologic process requires an extra step, it will generally take longer to finish than direct access. Thirdly, it is assumed that as reading ability develops (or familiarity with specific words increases) subjects will tend to bypass the phonological route and rely on the direct route for lexical access. Although dual route theory has been challenged in several ways, it still provides a useful theoretical framework and the idea of more than one pathway to lexicon has not been made implausible by research results (Pugh et al. 1994).

Pugh et al. (1994) suggest that the very existence of flexibility suggests that both phonological and direct processing are required in everyday reading, and that coding flexibility is highly practiced. These data suggest remarkably fine-tuned strategic adjustments in performance and suggest caution in interpreting lexical decision results without carefully examining the specific experimental context. Dual-route theories usually assume that with increased reading skill or word familiarity, reliance on orthographic information for accessing the lexicon should also increase.

To account for people's ability to pronounce both words that the reader has never seen before (including pseudowords, such as BINT) and words with exceptional or unconventional spelling-to-sound relations (e.g., AISLE and PINT), more than one way of generating a phonological output must exist. The speed with which subjects can name novel words or pseudowords suggests a compiled or assembled phonology, a process of early and efficient conversion from graphemic to phonologic codes. The ability to correctly pronounce words that violate typical grapheme-to-phoneme conversion rules (e.g., PINT) suggests a lexical constraint on phonological output and has been interpreted as evidence that phonological information (known as addressed phonology) can be recovered from the lexicon.

Flexibility in orthographic and phonological decoding strategy use can be directly assessed using a phoneme/grapheme deletion task, which generally requires subjects to delete a phoneme/grapheme from a word and blend the remaining sounds into a new word. Pronunciation of the residual word will differ according to whether a phonological strategy is demanded, so the phonological cues of the initial word are referenced, or whether an orthographic strategy is required, so the remaining spelling is referenced. For example, "cone" sounds like "own" with the /c/ deleted, but without the letter "c" it spells "one".

Lenchner, Gerber, and Routh (1990) compared six measures of phonological awareness including tasks that require the ability to segment, blend, and manipulate phoneme/graphemes. They suggest that deletion of a consonant is the most valid of the various measures of phonological awareness; correlating most highly with other phonological awareness tasks and with measures of phonetic decoding.

Children who are competent at deletion tasks appear to use orthographic strategies mainly with words and phonological strategies equally for words and non-words (Stuart, 1990). These two strategies are accommodated well by a dual-route model of spelling; a lexical route reserved for words and a sub-lexical route available for words and non-words. For spelling and deletion tasks, good spellers access both routes while poor spellers are limited to the sub-lexical route.

The present study manipulates strategy choice using visual and auditory presentation, phoneme or grapheme deletion, and instructions directing attention to the word's spelling or sound. Orthographic response instructions are consistent with visual presentation of words since the word's graphemes (spelling) must be addressed for a correct response. Phonological instructions are consistent with the auditory modality because the phonemes/graphemes needed for a correct response are provided. When an orthographic response is required and the word is orally presented then the word sounds must be ignored or an incorrect phonological response will be given. When a phonological response is needed and the word is visually presented then the spelling must be ignored or an incorrect orthographic response will result. When modality is inconsistent with response instructions, these tasks should be more difficult since they rely more heavily on the central executive control system of Baddeley's (1986) working memory model. Spelling and reading tasks are also included in this study. Shankweiler and Crain (1986) state that reading skill is highly correlated to measures of central executive capacity and it is this system that coordinates the manipulation (deletion) and blending of word parts.

This study will investigate the development of working memory capacity and strategy use in normal reading development in order to map the development of these two processes across a range of ages. It is hypothesised that younger children will be more successful using a phonological strategy than an orthographical strategy whereas young adults will be able to use either strategy equally well. It is hypothesised that performance on the reading/spelling task will correlate with performance on the phoneme/grapheme deletion task. It is further hypothesised that younger readers will have smaller working memory capacities than older readers particularly for word stimuli. Working memory span for digits is hypothesised to be greater than for non-rhyming words which will be greater than for rhyming words. Grade and performance on phoneme/grapheme deletion, working memory, and reading/spelling tasks are hypothesised to be correlated.

Method

Participants

Participants were students from four high schools and five primary schools in differing areas ranging from high to low socioeconomic status in Southern Tasmania. One hundred male(56) and female(44) students were randomly selected from grades 2, 4, 6, 8, and 10. Table 1 shows demographic data of participants.

Design

The experiment was a [5] x 2 x 2 design. The between subjects factor was grade. The within subjects factors were word presentation modality, which could be either visual or auditory, and response instructions, which required either phonological or orthographic answers. Thus, there were four tasks; visual presentation with phonological instructions (V/P), visual presentation with orthographic instructions (V/O), auditory presentation with phonological instructions (A/P), auditory presentation

Table 1

Demographic data of participants

Grade	Number of participants: Males	Females	Total	Average age (yrs, mths)
2	10	10	20	8,1
4	10	10	20	9,10
6	12	8	20	11,8
8	11	9	20	13,10
10	13	7	20	15,9

with orthographic instructions (A/O). These four tasks were combined to form a further independent variable, the number of consistent answers (i.e., visual presentation with orthographic response/ auditory presentation with phonological response required), and inconsistent answers (i.e., visual presentation with phonological response/ auditory presentation with orthographic response required) for each group and task. The dependent variable was the number of correct answers.

The ability of participants to spell and read all variations of the stimulus words was assessed using a [5] x 2 design. The between subjects factor was grade. The within subjects factor was type of task, either spelling or reading. The dependent variable was the number of correct spellings or pronunciations of the stimuli words.

The second part of the experiment involved measuring working memory span for words and digits which was a [5] x 3 x 2 design. The between subjects factor was grade. The within subjects factors were stimuli type (rhyming words, non-rhyming words, and digits) and response instructions, which required responding either forwards or backwards.

Correlational analysis was performed on all independent variables.

Word stimuli

The word stimuli were isolated words. The visually presented words were printed in black, lower case, Avant Garde font, sized 24 point on white cards sized 15 x 10 cms. The 22 words, comprised of 4 example words and two lists of 9 words, were taken from the Macquarie Dictionary (1991) (See Appendix A). The word set administered in the V/P task was also given in the A/O task, and the word set administered in the V/O task was also given in the A/P task. Table 2 shows the numbers of different positions of letter deletions in each list. For each word, deletion of one phoneme/grapheme, which was not silent or part of a digraph, produced a new real word which could be spoken according to the phonological cues of the initial word or according to the spelling of the remaining word, producing two different pronunciations. For example, "cone" becomes "own" phonologically or "one" orthographically, when the /c/ or "c" is removed. Words with multiple pronunciations were excluded (e.g., "ready" with the "y" deleted produces two correct orthographic responses which sound like "red" (same as phonological response) or "reed"). Also, words could not have the same orthographic and phonological answers after deletion (e.g., "cat" with "c" deleted is pronounced "at" orthographically and phonologically).

Working memory stimuli consisted of rhyming and non-rhyming words (see Appendix A) and digits (Digit Span, Wechsler Adult Intelligence Scale-Revised (Wechsler, 1981)). All stimuli were presented auditorily to the child as in the WAIS-R.

Table 2

The number of words for each position of letter deletion in each list

Deletion		List	
Position of letter	Letter type	V/P, A/O	V/O, A/P
Initial	consonant	2	2
Second serial position	consonant	2	2
Second last serial position	consonant	3	3
Final	consonant	2	2

Procedure

All tests were individually administered to children in the following order: phoneme/grapheme deletion task, spelling task, reading task, and working memory task. The four components of the phoneme/grapheme deletion task were counterbalanced as were the six components of the working memory task (see Appendix B). Spelling and reading tests of all variations of stimulus words used in phoneme/grapheme deletion task were given for control purposes (see Appendix A). Each task was administered according to a specific set of instructions (see Appendix A). For the phoneme/grapheme deletion task, the test was explained to the child and four practice words were presented, two orally and two visually. For each practice word, orthographic and then phonological instructions were given. Correct responses were supplied if necessary. In the visual condition, instructions were to look at the word but not to say it, and in the auditory condition to listen to the word. In the orthographic tasks, children were asked to remove a specific letter and say what the new word spelled. In the phonological tasks, children were asked to remove a specific sound and say what sound remained.

The experimenter did not read out the visually presented word or repeat the pronunciation of the orally presented word in the auditory condition. The child's responses were recorded on the score sheets (see Appendix A).

For the spelling task, the child was asked to write down how they thought the words would be spelled, being encouraged to attempt all words. The child was then asked to read each word aloud and their attempts recorded on the score sheet.

The working memory tasks were presented to the child as a remembering game in which they were asked to copy what the experimenter said in the words forwards condition, and to repeat the given sequence backwards in the words backwards conditions. After success on a practice item, all other items were presented at a rate of one per second per trial as for the Wechsler Adult Intelligence Scale (WAIS-R) (Wechsler, 1981). All responses given by the child were recorded on the score sheet. For the word tasks, all levels were completed for all children, however, for the digit tasks the task was discontinued when the child failed both trials of a level as for the digit span task in the WAIS-R.

Results

The mean number of correct responses and associated standard deviations, achieved by each grade in each task (V/O, V/P, A/O, A/P) were calculated (See Appendix C). A between groups, within participants {5[group] x 2(modality) x 2(instructions)} analysis of variance (ANOVA) was performed on the correct response data. A between groups, within participants {5[group] x 2(response)} analysis of variance (ANOVA) was performed on the consistent/inconsistent correct response data. Spelling and reading correct responses were analysed (See Appendix D) using a between groups, within participants {5[group] x 2(task)} ANOVA. A between groups, within participants {5[group] x 3(stimuli type) x 2(instructions)} MANOVA was performed on the working memory span data (See Appendix E). The significance level was set at $p < 0.05$. Student Newman Keuls post hoc tests (SNKs) were used to test differences between individual means where necessary. Grade, performance on each of the phoneme/grapheme deletion tasks (V/O, V/P, A/O, A/P), number of words read correctly, number of words spelled correctly, and span measures for rhyming words backwards and forwards, words backwards and forwards, and digit backwards and forwards were subjected to correlational analysis.

Correct response data

The correct response data was analysed to compare each grade's decoding ability. The analysis indicated a significant group main effect ($F(4,95)=18.64$, $p < .0001$). Students from grades 2 and 4 scored 3.53 and 5.11 mean correct responses respectively across all conditions, which were significantly lower than the mean 6.36, 7.08, and 6.88 correct responses scored by grades 6, 8, and 10 respectively (SNKs). The difference in mean correct responses for grades 2 and 4 was also significant.

There was a significant modality x instruction interaction ($F(1,95)=153.04$, $p < .0001$) which is illustrated in Figure 1. As can be seen in Figure 1, significantly more correct responses were made when orthographic instructions, rather than phonological instructions, were given in the visual presentation condition (SNKs). Conversely, in the auditory presentation condition significantly more correct responses were made when phonological instructions were issued than when orthographic instructions were issued (SNKs).

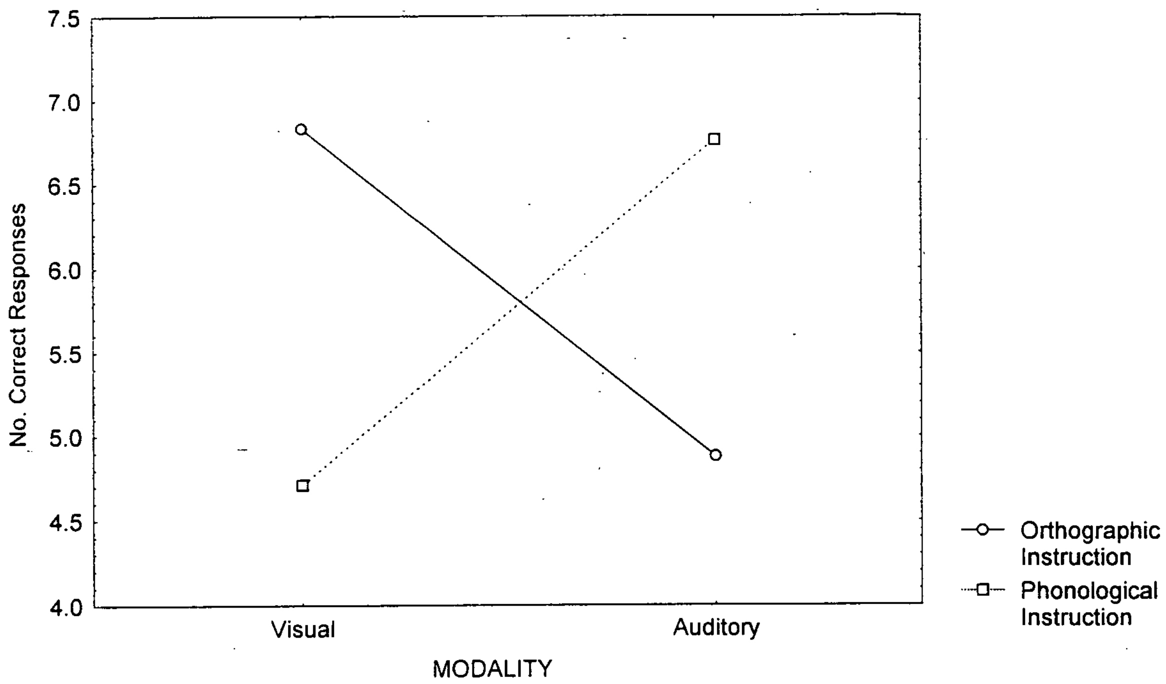

Figure 1. Number of correct orthographic and phonological responses in phoneme/grapheme deletion task as a function of presentation modality for all grades.

The group x modality x instruction interaction was also significant (F(4,95)=3.56, $p < .01$). As can be seen in Figure 2, the performance of children in the different grades varied depending not only on the modality of presentation but also on the type of response instruction issued. SNKs showed that performance generally improved as grade increased up to grade 6 and then plateaued. Grade 2 scored significantly lower than all other grades when orthographic responses were required in both modalities. The increase in performance observed between grade 2 and 6 for the A/O task was significant however, between grade 6 and 10 no significant differences in performance were found. While there was a general improvement in performance as grade increased for phonological instructions in the auditory modality it was not significant. A general improvement in performance was observed as grade increased for the V/P task, although the increases between adjacent grades were not significant. For the V/O task, the improvement in performance between grade 2 and 4 was significant, although there were no significant differences in performance between grade 4 and 10.

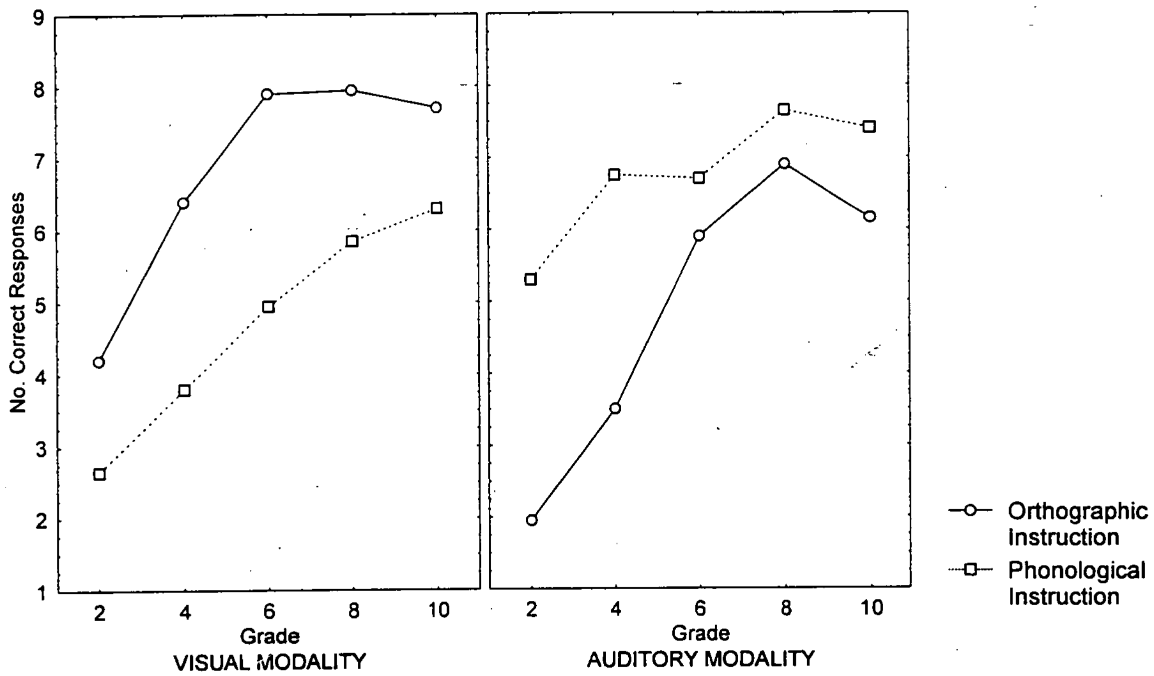

Figure 2. Number of correct orthographic and phonological responses as a function of presentation modality for each grade.

In the visual modality, performance on the orthographic task was greater than on the phonological task across all grades. Conversely, in the auditory modality, performance on the phonological task was greater than performance on the orthographic task across all grades which suggested that performance would be better on consistent responses than on inconsistent responses. Therefore a [5(grade)] x 2 (consistent/inconsistent) analysis of variance was performed on the data.

This analysis indicated a significant group main effect ($F(4,95)=18.64$, $p < .0001$) again showing that performance generally improved as grade increased. The analysis indicated a significant main effect for response type ($F(1,95)=153.04$, $p < .0001$). The mean correct response score for consistent responses (6.80) was significantly higher than the score obtained for inconsistent responses (4.80). There was a significant grade x response type interaction ($F(4,95)=3.56$, $p < .01$) which is illustrated in Figure 3.

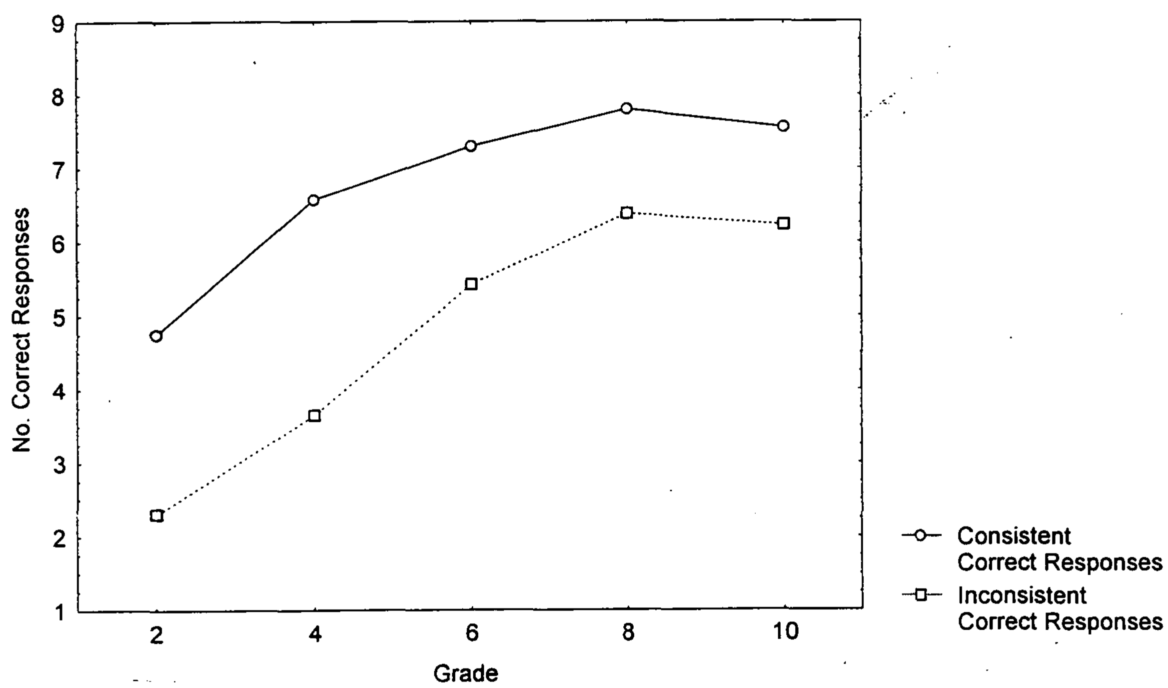

Figure 3. Number of correct consistent and inconsistent responses as a function of grade for phoneme/grapheme deletion task.

The mean number of correct consistent and inconsistent responses increased as grade increased from grade 2 to 6 and then plateaued. SNKs showed that the mean number of correct consistent responses increased significantly from grade 2 to 6, however, there were no significant differences in the scores achieved from grade 6 to 10. A significant improvement in performance was found from grade 2 to 8 for correct inconsistent responses, although there was no significant difference between scores obtained in grade 8 and 10. Across all grades, there were significantly more correct consistent responses than correct inconsistent responses.

<u>Spelling and reading data</u>

The spelling and reading data was also analysed with a [5 (grade)] x 2 (task, spelling/reading) ANOVA. There was a significant main effect for grade ($F(4,94)=17.22$, $p < .0001$). Performance increased from grades 2 to 6 and then levelled off from grades 6 to 10. Performance by grades 2 and 4 was significantly different to all other grades, although there were no significant differences in performance from grade 6 to 10 (SNKs). A significant main effect was also found for task (spelling or reading) ($F(1,94)=63.40$, $p < .0001$). Across all grades, performance was significantly better on the reading rather than the spelling task. The grade x task interaction ($F(4,94)=8.80$, $p < .0001$) was significant. As can be seen in Figure 4, dramatic improvements were made in both tasks from grade 2 to 6 and then a levelling out in performance was observed from grade 6 to 10. The improvements in the reading task from grade 2 to 6 were significant (SNKs). For the spelling task, there was a significant improvement in performance from grade 2 to 6, followed by a non-significant decrease in performance between grade 6 and 8 and a significant decrease from grade 8 to 10. Students in grades 2, 4, and 10 performed significantly better on the reading task rather than the spelling task, while at grades 6 and 8 the difference in performance was not significant (SNKs).

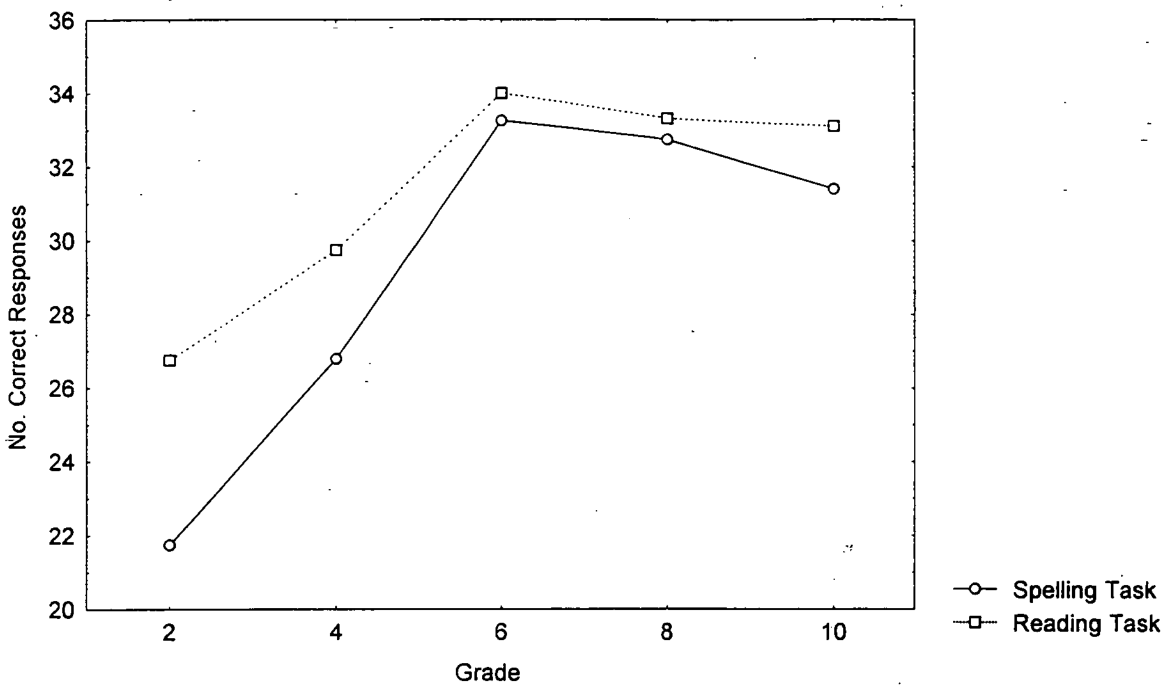

Figure 4. Number of correct responses for spelling and reading tasks for each grade.

Working memory data

The working memory data was analysed with a [5(grade)] x 3(stimuli type) x 2(instructions) MANOVA. The analysis indicated a significant group main effect ($F(4,94)=8.90$, $p < .0001$). Grades 2 and 4 achieved mean working memory spans of 2.98 and 3.17 respectively across all conditions, which were significantly lower than the mean working memory spans, 3.58, 3.65, and 3.69 achieved by grades 6, 8, and 10 respectively (SNKs). The difference in mean working memory span for grades 2 and 4 were not significant. Likewise, the differences in span for grades 6, 8, and 10 were not significantly different (SNKs).

There was a significant main effect for type of stimuli (rhyming words, non-rhyming words, and digits) (Rao $R(2,93)=66.81$, $p < .0001$). The mean working memory span for digits (3.97) was significantly greater than the span for non-rhyming words (3.31) which was significantly greater than the span (2.96) for rhyming words.

A significant main effect was found for the type of response instruction issued (F(1,94)=462.18, p < .0001). The mean working memory span for forwards recall of stimuli (4.01) was significantly greater than the span for backwards recall (2.81).

A significant stimuli type x response instruction interaction was found (Rao R(2,93)=12.47, p < .0001). As can be seen in Figure 5, the mean working memory span for forwards recall was significantly greater than the span for backwards recall for all stimuli types, however the difference was larger for digits than for either of the two word conditions.

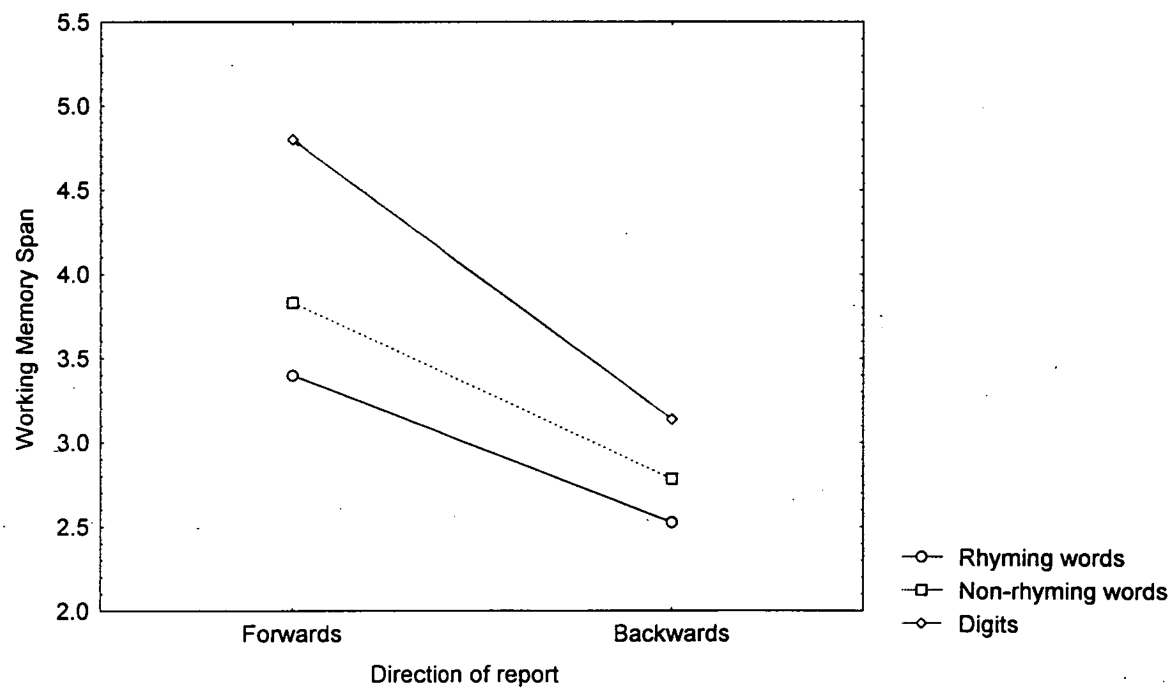

Figure 5. Working memory span for rhyming and non-rhyming words and digits as a function of direction of report.

For forwards recall, the mean working memory span for digits (4.80) was significantly greater than span for non-rhyming words (3.83) which was significantly greater than span for rhyming words (3.40). For backwards recall, the mean working memory span for digits (3.14) was significantly greater than the span for non-rhyming words (2.78) which was significantly greater than the span for rhyming words (2.53).

There was a significant grade x stimuli type x response instruction interaction (Rao $R(8,186)=2.10$, $p < .038$). As can be seen in Figure 6, the performance of children in the different grades varied depending not only on the type of stimuli they were required to recall but also on the type of response instruction issued (the direction in which children were asked to recall the stimuli, either forwards or backwards). SNKs showed that there were some slight improvements in performance across grades depending on the task.

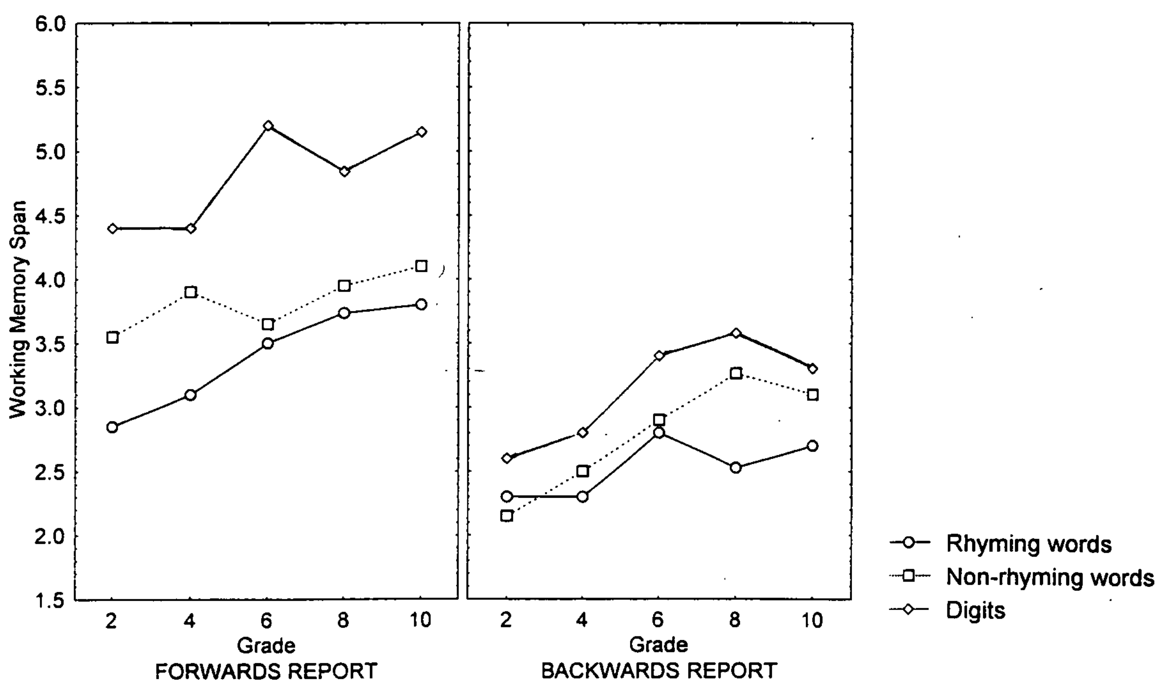

Figure 6. Working memory span for rhyming and non-rhyming words and digits as a function of direction of report for each grade.

A general improvement in working memory span across grades was observed for the rhyming words/forwards task although none of these were significant. There were no significant improvements in working memory span for non-rhyming words/forwards task across grades. The only significant improvement made in span on the digits/forwards task was between grades 4 and 6. Performance on the digits forwards task was significantly better than performance on the rhyming words/forwards task at each grade level. Working memory span on the digits forwards task was significantly better than on the non-rhyming words/forwards task at grades 2,6,8 and 10. Regardless of whether children were required to recall stimuli forwards or backwards (in both forward and backward recall conditions) working memory span was generally largest across all grades for digits, followed by non-rhyming words and then rhyming words. While there tended to be improvements made in working memory span across grades for all three types of stimuli in the backwards recall condition, they were not significant (SNKs). The only significant difference observed in working memory span between stimuli type was between digits/backwards and rhyming words/backwards at grade 8; there were no other significant differences in working memory span between stimuli types at each grade level.

Correlational data

Correlations were used to investigate the relationship between the 12 tasks performed by participants (phoneme/grapheme deletion tasks (4), spelling, reading, and working memory tasks (6)) and grade. The logarithm of the grade variable was used to allow for non-linearity of the developmental effects. As can be seen in Table 3, grade was low to moderately positively correlated with the tasks performed by participants, with the strongest correlations being between grade and both the orthographic tasks and spelling and reading. Correlations between V/O and A/O tasks (0.77) and between V/P and A/P tasks (0.59) were higher than correlations between V/O and V/P tasks (0.48) and between A/O and A/P tasks (0.30). Orthographic and phonological tasks in the visual modality (0.48) were more highly correlated than the two tasks in the auditory modality (0.30). Orthographic tasks regardless of modality were highly correlated with performance on the spelling and reading tasks, more highly correlated than phonological tasks in either modality. Performance on the spelling and reading tasks was very highly correlated (0.9). Low correlations were found between the working memory tasks. Generally, low correlations were found between the forwards and backwards working memory span measures for each type of stimuli (rhyming, non-rhyming words, and digits). Digits forwards and backwards were the most correlated (0.39), followed by non-rhyming words forwards and backwards (0.25), and rhyming words forwards and backwards (0.19).

Discussion

The results of this study show that decoding ability improves with age. Younger children in grades 2 and 4 did significantly more poorly on the phoneme/grapheme deletion task than children in grades 6, 8, and 10. Normal reading development is characterised by a developmental increase in decoding ability together with an increase in the size of sight vocabulary (Snowling, 1980). Generally, there appeared to be an improvement in performance on the deletion task as grade increased, although this was dependent on the modality of presentation of stimuli and the type of response which was required.

Table 3

Correlations between test scores

	1	2	3	4	5	6	7
1. LOGGRADE	--	.664**	.457**	.595**	.353**	.606**	.544**
2. VMORO		--	.478**	.765**	.320**	.756**	.719**
3. VMPRP			--	.551**	.593**	.551**	.578**
4. AMORO				--	.304**	.758**	.672**
5. AMPRP					--	.386**	.400**
6. NOCSPELL						--	.899**
7. NOCREAD							--
8. RWFSPAN							
9. WFSPAN							
10. DFSPAN							
11. RWBSPAN							
12. WBSPAN							
13. DBSPAN							

	8	9	10	11	12	13
1. LOGGRADE	.443**	.228*	.253*	.226*	.505**	.316**
2. VMORO	.354**	.170	.270**	.284**	.449**	.240*
3. VMPRP	.302**	.182	.340**	.346**	.387**	.288**
4. AMORO	.427**	.242*	.293**	.288**	.384**	.280**
5. AMPRP	.234*	.169	.199*	.197	.390**	.348**
6. NOCPSELL	.312**	.182	.282**	.319**	.407**	.266**
7. NOCREAD	.325**	.181	.247*	.378**	.388**	.317**
8. RWFSPAN	--	.208*	.200*	.194	.380**	.404**
9. WFSPAN		--	.425**	.106	.248*	.296**
10. DFSPAN			--	.224*	.383**	.390**
11. RWBSPAN				--	.186	.205*
12. WBSPAN					--	.325**
13. DBSPAN						--

Note. LOGGRADE = Log of grade. VMORO = Visual presentation, orthographic response required, orthographic response given. VMPRP = Visual presentation, phonological response required, phonological response given. AMORO = Auditory presentation, orthographic response required, orthographic response given. AMPRP = Auditory presentation, phonological response required, phonological response given. NOCSPELL = Number of correct spelling responses. NOCREAD = Number of correct reading responses. RWFSPAN = Rhyming words forwards span. WFSPAN = Non-rhyming words forwards span. DFSPAN = Digit span forwards. RWBSPAN = Rhyming words backwards span. WBSPAN = Non-rhyming words backwards span. DBSPAN = Digit span backwards.

** Correlation is significant at 0.01 level (2-tailed)

* Correlation is significant at 0.05 level (2-tailed).

When stimuli were presented visually, younger children (grades 2 and 4) appeared to find it easier to provide orthographic responses rather than phonological responses. Conversely, when stimuli were presented auditorily, children seemed to find it easier to provide phonological responses than orthographic responses. There were no significant differences between performances of older children (grades 6 to 10) on any of the four deletion tasks (A/O, A/P, V/O, V/P).

Children gave more correct consistent responses than inconsistent responses across all conditions. From grade 2 to 6, the number of consistent responses increased significantly and then plateaued from grade 6 to 10. For inconsistent responses, performance improved significantly from grade 2 to 8 and then levelled off. It appears that children can answer correctly for consistent responses at a younger age than for inconsistent responses. Performance on the phoneme/ grapheme deletion task, spelling and reading tasks and consistent response task all plateaued at grade 6 whereas performance for inconsistent responses did not plateau until grade 8 possibly indicating that this task is more difficult and requires skills that are acquired at a later age. It is plausible that as children mature they acquire the skills to answer correctly when given instructions that require a response which is inconsistent with modality of presentation.

Performance on the spelling and reading tasks increased from grades 2 to 6 and then plateaued from grades 6 to 10, indicating that children have acquired the skills to read and spell proficiently by age 12 years. Gathercole and Baddeley (1993) have suggested children read proficiently by 8 years of age which is supported by the moderate correlations between grade and reading/spelling performance (0.54 and 0.61 respectively) in this study. Performance on the reading task was better than on the spelling task across all grades. Reading performance was significantly better than spelling at grades 2, 4, and 10. This may reflect the use of both phonological and orthographic strategies in reading whereas children may tend to rely more on orthographic strategies when spelling.

Children who are good at reading and spelling are able to use both phonological and orthographic processing strategies in a deletion task (Stuart, 1990). The correlations between spelling and reading tasks and orthographic and phonological strategy use show not only that good reader/spellers use orthographic and phonological strategies well but that poor reader/spellers are not so competent at using these strategies. Stuart (1990) suggested that children who are competent at deletion tasks use both an orthographic strategy (mainly with words) and a phonological strategy (used equally for words and non-words). The current study did not use non-words although this could be an area for further research. Good spelling enables children to use orthographic strategies in supposedly "phonological" tasks like consonant deletion. Since their phonological skills are also better than those of poor spellers, they can use both orthographic and phonological strategies and tend to switch to phonological strategies when the stimulus is not a word. Burden (1989 as cited in Baddeley, 1992) has suggested that good readers develop a larger orthographic lexicon than poor readers which gives them a bigger data base from which sub-lexical spelling-to-sound correspondences are formed. Older children who performed better on spelling and reading tasks would be expected to have developed a larger orthographic lexicon than younger children. Grade and reading/spelling performance were moderately to highly correlated with performance on the deletion tasks which further extends Stuart's (1990) study since the current study has considered the effects of good and poor reading performance and age. As Stuart (1990) suggests, dual-route models of spelling accommodate these two strategies well, with a lexical route for words and a sub-lexical route available for both words and non-words.

Good spellers have access to both routes for spelling and deletion tasks, while poor spellers are mostly confined to the sub-lexical route.

Performance on spelling and reading tasks and orthographic tasks in both visual and auditory modalities were very highly correlated. Children who do well at reading/spelling tasks are likely to do well on orthographic tasks. Conversely, children who do poorly at reading and spelling are also likely to perform poorly on orthographic tasks. Orthographic strategy use was more highly correlated with reading and spelling tasks than phonological strategy use. Stuart (1990) found that children who were not good readers/spellers were largely incorrect in the deletion task and were significantly more likely to use a phonological strategy. The latter point is not clear from the results of this study, although younger children were able to produce a phonological response significantly more than an orthographic response in the auditory modality. However, orthographic strategy use increased as grade increased so that no significant differences existed between orthographic and phonological strategy use from grade 6 to 10. Also, Stuart's (1990) findings are a little unclear because his instructions ("Can you say it without the /s/ ?") were supposed to tap the participant's preferred strategy, however, they predisposed participants to use a phonological strategy. The instructions in the present experiment constrained the children's answers to be either phonological or orthographic as dictated by the experimenter.

Stuart's (1990) results and those of the current study also support the proposition that there are reciprocal influences between phonological awareness and the development of literacy skills. Children who showed advanced phonological skills as pre-readers became better readers and spellers and performed better on the deletion tasks (Stuart, 1990). Bertelson and de Gelder (1988) claim that literacy skills play an indirect role in the ability of good reader/spellers to perform deletion tasks by allowing them to use orthographic knowledge to solve phonological problems. Poor reader/spellers have fewer stored orthographic representations and so cannot use an orthographic strategy. Stuart (1990) found that poor reader/spellers were worse at the deletion task using both phonological and orthographic strategies which suggests that experience of alphabetic orthography alone is not sufficient to teach speech segmentation at the phonemic level. Rather, early phonological awareness (a precursor of literacy) seems to allow good reader/spellers to use their experience of alphabetic orthography as a further aid to speech segmentation (a consequence of literacy). Poor reader/spellers continue to develop phonological skills as they learn to read but this can happen in isolation from the reading process and without reciprocal influence from orthographic experience (Stuart, 1990).

Working memory span increased from grades 2 to 10, with span for digits being the greatest, followed by span for non-rhyming words and then rhyming words. This confirms the phonological similarity effect (Conrad, 1964) such that it is more difficult to recall accurately words which sound similar. Working memory span for forwards recall was greater than span for backwards recall. The forward recall digit and word span tasks evaluate the storage aspect of working memory whereas backward recall span tasks evaluate storage and processing capacity. Backward recall may be more difficult than forwards recall because of the need to deploy executive resources for a verbal task when direction of report is backwards (Schofield & Ashman, 1986 as cited in Farrand & Jones, 1996). Smyth and Scholey (1992 as cited in Farrand & Jones, 1996) suggest that executive resources are required to reverse the order of presentation of verbal items since the list is probably rehearsed in the forward order and when prompted to recall subjects must assemble the reversed list. Rohl and Pratt (1995) claim that the simple repetition measure (forward recall) involved the operation of the articulatory loop since items had to be repeated exactly as spoken. However, backwards repetition may have involved the central executive since items had to be stored whilst control processing was invoked to regroup them in reverse order. Results from a study by Rohl and Pratt (1995) were compatible with Baddeley's model (1986) of verbal working memory, in which processing in the articulatory loop involves simple storage of items, whereas processing in the central executive involves storage and control processing.

Daneman and Carpenter (1980) measured working memory capacity using a task that required subjects to read a series of sentences and then recall the last word of each. The need to simultaneously comprehend and remember distinguished this from a simple word span task. They found this reading span measure of working memory to be a better predictor of reading ability than a simple word span measure, interpreting this to mean that efficient readers need fewer processing resources and so have greater functional storage capacity. Oakhill, Yuill, and Parkin (1988 as cited in Baddeley, 1995) showed that children who were good readers in the sense of being able to pronounce printed words, but poor comprehenders performed poorly on working memory span tasks. The results of this study show low correlations between working memory tasks and other variables which is supported by findings of Oakhill et al. (1988 as cited in Baddeley, 1995). Although we have no data in this study on comprehension ability of participants and so cannot confirm this aspect of the previous studies we have used word span measures and a reading task which taps the ability to pronounce printed words and thus can confirm that good readers may perform poorly on working memory tasks.

Grade was low to moderately correlated with working memory task performance showing that as children got older their working memory span did not necessarily increase. It may be possible that the working memory tasks in this experiment did not create a sufficient load on working memory so that it did not reach its full working capacity since capacity of working memory is thought to increase until about 11 years of age (Hitch, Halliday, & Littler, 1984). A reading span measure of working memory (Daneman & Carpenter, 1980) may have been more useful.

It seems that children who are good decoders reach a ceiling level of performance on phoneme/grapheme deletion tasks which suggests that only a certain threshold level of phonological awareness is necessary for decoding. Possibly, a more complex task, sensitive to individual differences among good decoders is needed to further develop understanding of reading processes. Nonwords or exception words could be used in future research to reduce the possibility that subjects use spelling strategies when performing tasks (Lenchner et al., 1990) since good decoders are also likely to be good readers/spellers.

In conclusion, the findings of this study have shown that decoding ability improves with age. Older children are able to use orthographic and phonological strategies equally well whereas younger children tend to use orthographic strategies with visually presented material and phonological strategies with auditorily presented material. Good decoders are also likely to be good readers/spellers since reading/ spelling performance, grade and performance on the phoneme/grapheme deletion task were moderately correlated. Working memory capacity seems to increase significantly between age 9 (grade 4) and 12 (grade 6) years so younger children do have smaller working memory capacities than older children particularly for word stimuli. Working memory span was greatest for digits, followed by non-rhyming words and rhyming words due to the phonological similarity effect. Working memory span as measured in this study produced only low correlations with performance on the phoneme/grapheme deletion task.

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Appendix A

GENERAL INSTRUCTIONS FOR ALL GRAPHEME/PHONEME DELETION TASKS

There are three tasks in this experiment.
These are
1. Phoneme/Grapheme Deletion Task
2. Spelling Task
3. Reading Task

And they should be completed in the order shown above:
First, deletion task according to order sheets and instructions for that task.
Second, spelling task according to instruction sheet for that task
Third, reading task according to instruction sheet for that task.

General instructions.

Establish rapport with the children adequately
Do not let the children see clearly what it is that you are writing

Remember to write at the top of every response sheet the name, grade, etc. of each child.

GRAPHEME/PHONEME DELETION TASK INSTRUCTIONS

INSTRUCTIONS - VISUAL PRESENTATIONS

Place the sheet in front of the child and cover with the card all the words except the first practice word. Say to the child " Now we are going to do a different kind of thing." If you have already run the auditory conditions then say " For some of the words I'm going to show you the words instead of saying them. I would now like you to look at the first word." If visual conditions are first then say " In this task I would like you to look at the first word." Then go on to instructions for the practice words.

Visual Presentation -

Instructions for first practice word for visual presentations:

"Look at this word, but do not say it. What would this word spell if it did not have a letter 's'. The answer is a new word. The answer is 'sew'. The answer 'sew' does not sound much like the word 'stew' does it? So what would this word sound like if it was said without the /s/ sound? The answer is /sue/ which is different to stew isn't it? This is what all the words will be like - when I tell you to take out a letter and then tell me what the rest of the word spells this will be a different answer to when I ask you to take out a sound and tell me what the rest of the word sounds like"

Instructions for the second practice word for visual presentation:

Move the card down the list so that the second word is exposed. "Look at this word but do not say it. What new word would this word spell if it did not have the letter 'n'. [Allow the child time to respond] That's right, the answer is 'get' but 'get' does not sound much like 'gent'. So what would this word sound like without the /n/ sound. [Allow the child time to respond] That's right, the answer is /jet/."

Then go on to the instructions for the particular response required.

Visual Presentation Orthographic Response Required

Move the card down the list so that the next word is exposed. Say: "What would this word spell if I took out the letter 'deleted letter'?
Tick the response sheet for the response the child made and if neither response was made write down the word the child says in the other column. If the child says more than one word write them all down in the order said.

Visual Presentation - Phonological Response Required

Move the card down the list so that the next word is exposed. Say: "What would this word sound like if the /deleted sound/ was removed?"
Tick the response sheet for the response the child made and if neither response was made write down the word the child says in the other column. If the child says more than one word write them all down in the order said.

INSTRUCTIONS - AUDITORY PRESENTATIONS

Say to the child " Now we are going to do a different kind of thing." If you have already run the visual conditions then say " For some of the words I'm going to say the words instead of showing them to you. Listen to the first word." If visual conditions are first then say " In this task I would like you to listen to this word." Then go on to instructions for the practice words.

AUDITORY PRESENTATIONS

Instructions for first practice word for auditory presentations:

"For these words I'll say them to you (if visual conditions have already been run say "instead of showing them to you" "For the spelling answers you will have to picture the word in your head and all the letters that make it up. OK, so think about how the word 'dare' is spelt - if you pretend the 'd' never existed, what would the words spell? The answer is a new word. The answer is 'are'. The answer 'are' does not sound much like the word 'dare' does it? So what would this word sound like if it was said without the /d/ sound? The answer is /air/ which is different to dare isn't it? This is what all the words will be like - when I tell you to take out a letter and then tell me what the rest of the word spells this will be a different answer to when I ask you to take out a sound and tell me what the rest of the word sounds like"

Instructions for the second practice word for auditory presentations:

Say " Think about how the word 'boat' is spelt - if you pretend that the letter 't' never existed, what would the letters left spell? What new word would this word spell if it did not have the letter 't'. [Allow the child time to respond] That's right, the answer is 'boa' but 'boa' does not sound much like 'boat'. So what would this word sound like without the /t/ sound. [Allow the child time to respond] That's right, the answer is /bow/."

Then go on to the instructions for the particular response required.

Auditory Presentation - Orthographic Response Required
'What new word would the word <word> spell if the letter <deleted letter> did not exist?'

Tick the response sheet for the response the child made and if neither response was made write down the word the child says in the other column. If the child says more than one word write them all down in the order said.

Auditory Presentation - Phonological Response Required
What does <word> sound like without the /deleted sound/?

Tick the response sheet for the response the child made and if neither response was made write down the word the child says in the other column. If the child says more than one word write them all down in the order said.

Grapheme/Phoneme Deletion Task - Response Sheet

Name:	*Age*	*Grade*	*School*

Auditory Presentation - Phonological Response Required

beard
snow
meant
climb
bread
surge
cast
hind
friend

Word	*letter*	*Phon Resp*	*Orth Resp*	*Other*
Practice Items				
dare	***d***	***air***	***are***	
boat	***t***	***bow***	***boa***	
Test Items				
beard	*d*	*beer*	*bear*	
snow	*s*	*no*	*now*	
meant	*t*	*men*	*mean*	
climb	*k*	*lime*	*limb*	
bread	*r*	*bed*	*bead*	
surge	*j*	*sir*	*sure*	
cast	*s*	*cart*	*cat*	
hind	*n*	*hide*	*hid*	
friend	*r*	*fend*	*fiend*	

Name: ______ *Age* ______ *Grade* ______ *School* ______

Visual Presentation - Orthographic Response Required

climb
hind
bread
surge
beard
meant
friend
snow
cast

Word	*letter*	*Phon Resp*	*Orth Resp*	*Other*
Practice Items				
stew	***t***	***sue***	***sew***	
gent	***n***	***jet***	***get***	
Test Items				
climb	*c*	*lime*	*limb*	
hind	*n*	*hide*	*hid*	
bread	*r*	*bed*	*bead*	
surge	*g*	*sir*	*sure*	
beard	*d*	*beer*	*bear*	
meant	*t*	*men*	*mean*	
friend	*r*	*fend*	*fiend*	
snow	*s*	*no*	*now*	
cast	*s*	*cart*	*cat*	

Grapheme/Phoneme Deletion Task: Response Sheet

Name: ______ ***Age*** ______ ***Grade*** ______ ***School*** ______

Auditory Presentation - Orthographic Response Required

cone
barge
pearl
pretty
thought
past
sweat
broad
rind

Word	*letter*	*Phon Resp*	***Orth Resp***	*Other*
Practice Items				
dare	***d***	***air***	***are***	
boat	***t***	***bow***	***boa***	
Test Items				
cone	*c*	*own*	*one*	
barge	*g*	*bar*	*bare*	
pearl	*l*	*purr*	*pear*	
pretty	*r*	*pity*	*petty*	
thought	*t*	*thaw*	*though*	
past	*s*	*part*	*pat*	
sweat	*w*	*set*	*seat*	
broad	*b*	*roared*	*road*	
rind	*n*	*ride*	*rid*	

Name: ______ *Age* ______ *Grade* ______ *School* ______

Visual Presentation - Phonological Response Required

past
sweat
broad
rind
pearl
thought
pretty
cone
barge

Word	*letter*	***Phon Resp***	*Orth Resp*	*Other*
Practice Items				
stew	***t***	***sue***	***sew***	
gent	***n***	***jet***	***get***	
Test Items				
past	*s*	*part*	*pat*	
sweat	*w*	*set*	*seat*	
broad	*b*	*roared*	*road*	
rind	*n*	*ride*	*rid*	
pearl	*l*	*purr*	*pear*	
thought	*t*	*thaw*	*though*	
pretty	*r*	*pity*	*petty*	
cone	*k*	*own*	*one*	
barge	*j*	*bar*	*bare*	

Instructions for Spelling Task

Take out the spelling task response sheet and the spelling task stimuli sheet.

Say to the child

'I would now like to see how many words you can spell. Here is your sheet. I would like you to write down how you think these words would be spelled. You start with number 1 and then go on to number 2. When we have finished number 8 I would like you to turn over the page and start with number 9."

Make sure each child writes the spelling of the word next to the correct number.
Give the spelling practice words and then go on to the experimental words.
Complete (or at least attempt) all words
Give the stimuli for the spelling task exactly as written on the spelling task stimuli sheet.
Encourage the child to complete each word.

SPELLING TASK stimuli

Practice words

1. dare.....The climbed on the roof for a dare.....dare
2. boat.....The children went for a ride on the boat.....boat
3. stew.....They had stew for dinner.....stew
4. gent.....The gent went for a walk...gent
5. are.....They are going for a walk.....are
6. boa.....The boa constrictor wrapped himself around the dog......boa
7. sew.....I went to a sewing class to learn to sew...sew
8. get.....I will get the dinner.....get

Experimental Words:

9. beard...The old man had a long beard.....beard
10. snow....In winter, we play in the snow.....snow
11. meant.....We meant to be nice, but she thought we were mean......meant
12. climb.....When I grow up I will climb mountains.....climb
13. bread.....The bread was covered with jam......bread
14. surge.....The surge of the tide surprised everyone......surge
15. cast.....When I broke my leg, the doctor put a plaster cast on it......cast
16. hind.....The hind leg of the cow was broken.......hind
17. friend......My friend is always nice to me.......friend
18. cone.....My mother said she would buy me an ice-cream cone if I was good.......cone
19. barge....The barge carrying coal up the river stopped at the wharf......barge
20. pearl......I wish I could find an oyster with a pearl in it.........pearl
21. pretty....My friend's new dress is very pretty......pretty
22. thought....I thought I could do it, but I was wrong.......thought
23. past.......We can learn important things from the past.......past
24. sweat.....When the weather is hot we sometimes sweat.........sweat
25. broad......The road was very broad.......broad
26. rind......I peeled the rind off the orange......rind
27. bear......The bear liked the honey we gave it to eat......bear
28. now......I would like you to do it now........now
29. mean......Do you mean it or are you joking.......mean
30. limb........In the big storm, a limb fell off the tree......limb
31. bead.......My mother lost a bead from her necklace.......bead
32. sure......I am sure that you will like it.......sure
33. cat......The cat ate some fish for dinner.........cat
34. hid.......I hid in the cupboard when I was playing hide-and-seek.......hid
35. fiend.....I saw a fiend on a television show.......fiend
36. one......The first number when you are counting is one.......one
37. bare......The tree was bare because it had lost all it's leaves.......bare
38. pear.......I ate a pear for lunch.......pear
39. petty.......My mother said it was petty to worry about little things......petty
40. though......I am tall even though I am still young.......though
41. pat......I bent to pat the dog......pat
42. seat......I was sitting on a wet seat........seat
43. road.......The road was very steep........road
44. rid......We get rid of the rubbish at the tip.......rid.

SPELLING TASK: RESPONSE SHEET

***Name:*................................*Grade:*.......*Age*..........*Date*............**

Practice Words:

1. .... 5. ....
2. .... 6. ....
3. .... 7. ....
4. .... 8. ....

SPELLING TASK: RESPONSE SHEET

Experimental Words:

9. ....
10. ....
11. ....
12. ....
13. ....
14. ....
15. ....
16. ....
17. ....
18. ....
19. ....
20. ....
21. ....
22. ....
23. ....
24. ....
25. ....
26. ....
27. ....
28. ....
29. ....
30. ....
31. ....
32. ....
33. ....
34. ....
35. ....
36. ....
37. ....
38. ....
39. ....
40. ....
41. ....
42. ....
43. ....
44. ....

Instructions for Reading Task

Turn to the page in the test booklet headed reading task.
Allow the child to read at his own pace the eight practice words - words are to be read across the page (i.e., for the first list dare, boat, stew, gent etc.)
Say to the child

'I would like you to read these words for me. Read one row (point) and then go down and read the second row)."

Continue till the end of the reading test.
Scoring - tick the score sheet if the child gets the correct pronunciation, otherwise write down what the child says. If the child makes greater than 1 attempt at the word, write down each attempt.

READING TASK: SCORE SHEET

***Name:*................................*Grade:*.......*Age*.........*Date*............**

Practice Words:

1. dare...
2. boat...
3. stew...
4. gent...
5. are...
6. boa...
7. sew...
8. get...

Experimental Words:

9. beard...
10. snow...
11. meant...
12. climb...
13. bread...
14. surge...
15. cast...
16. hind...
17. friend...
18. cone...
19. barge...
20. pearl...
21. pretty...
22. thought...
23. past...
24. sweat...
25. broad...
26. rind...
27. bear...
28. now...
29. mean...
30. limb...
31. bead...
32. sure...
33. cat...
34. hid...
35. fiend...
36. one...
37. bare...
38. pear...
39. petty...
40. though...
41. pat...
42. seat...
43. road...
44. rid...

WORKING MEMORY INSTRUCTIONS

Instructions to the children:

Simple repetition - words and digits forwards
We're going to play a remembering game. You have to copy what I say. Listen carefully and then say just what I say. If you don't hear me properly then ask me to say it again - but you must ask me to say it again before you start to say it. First I'll give you some practice. Remember, you say just what I say.

Present practice item: Give feed back if incorrect.
Present all other items at the rate of one per second per trial as for the WAIS. Write the number of the word as each child says it in the space on the response sheet. If the child says other words write them down in the order the child says them.

Criteria for stopping: Complete all levels for all children.

Backwards repetition - words and digits backwards
Now we're going to say some backwards. If I say 'tall head' (or 8 2), I want you to say 'head tall' (or 2 8). If I say 'tall head' (or 8 2), what do you say? Good! And if I say 'red got' (or 7 1), what do you say? Great! Now you know what to do. [If the child did not answer correctly, then corrective feedback was given. No, you would say 'got read' (or 1 7). I said 'red got' (or 7 1), so to say it backwards you say 'got red' (or 1 7). What would you say?]

Present practice item: Give feed back if incorrect.
Present all other items at the rate of one per second per trial as per WAIS. Write the number of the word as each child says it in the space on the response sheet. If the child says other words write them down in the order the child says them.

Criteria for stopping: Complete all levels for all children.

Name..
School..
Age..
Date..
Test Order..
Teacher..
Grade..

MEMORY FOR WORDS - RHYMING

Practice items feet beat

wide[1] ride[2]
log[1] dog[2]
seed[1] lead[2] need[3]
coat[1] boat[2] goat[3]
nail[1] tail[2] sail[3] mail[4]
ball[1] fall[2] tall[3] call[4]
said[1] bed[2] led[3] head[4] red[5]
sun[1] gun[2] run[3] bun[4] fun[5]
bill[1] fill[2] hill[3] kill[4] pill[5] will[6]
hot[1] lot[2] got[3] cot[4] dot[5] not[6]
can[1] fan[2] man[3] pan[4] ran[5] tan[6] van[7]
bait[1] gate[2] hate[3] late[4] mate[5] wait[6] date[7]

Total correct.................................

Words Backwards

Practice Items mate wait, man can

hot[1] got[2]
pan[1] ran[2]
seed[1] need[2] lead[3]
boat[1] coat[2] goat[3]
nail[1] mail[2] tail[3] sail[4]
call[1] ball[2] fall[3] tall[4]
said[1] bed[2] red[3] led[4] head[5]
fun[1] gun[2] sun[3] run[4] bun[5]

Total Correct...................................

Total Score...............................

Name..
School..
Age...
Date..
Test Order..
Teacher...
Grade...

MEMORY FOR WORDS - NON-RHYMING Simple Repetition forwards test

Practice items - beat cake-

ball[1] cot[2]
not[1] tan[2]
sun[1] wait[2] call[3]
sail[1] bed[2] hot[3]
gate[1] said[2] lot[3] hill[4]
ran[1] dot[2] led[3] nail[4]
log[1] fill[2] need[3] man[4] hate[5]
goat[1] pill[2] bait[3] lead[4] fun[5]
mate[1] ride[2] gun[3] boat[4] fall[5] pan[6]
head[1] bill[2] date[3] tall[4] fan[5] seed[6]
late[1] van[2] kill[3] bun[4] red[5] tail[6] got[7]
mail[1] dog[2] wide[3] run[4] coat[5] will[6] can[7]

Total correct.........................

Words Backwards

Practice Items tall head, red got

dog[1] wide[2]
late[1] red[2]
bed[1] hot[2] sail[3]
sun[1] call[2] wait[3]
said[1] lot[2] gate[3] hill[4]
led[1] nail[2] ran[3] dot[4]
log[1] hate[2] need[3] man[4] fill[5]
fun[1] bait[2] goat[3] pill[4] need[5]

Total Correct..................................

Total Score.........................

Name.. **Test Order**.......................
Teacher.. **School**...........................
Age.. **Date**.............................
Grade...

MEMORY FOR DIGITS *Simple Repetition forwards test*

Practice items 8 2

2^1 9^2

4^1 6^2

3^1 8^2 6^3

6^1 1^2 2^3

3^1 4^2 1^3 7^4

6^1 1^2 5^3 8^4

8^1 4^2 2^3 3^4 9^5

5^1 2^2 1^3 8^4 6^5

3^1 8^2 9^3 1^4 7^5 4^6

7^1 9^2 6^3 4^4 8^5 3^6

5^1 1^2 7^3 4^4 2^5 31^6 8^7

9^1 8^2 5^3 2^4 1^5 6^6 3^7

1^1 6^2 4^3 5^4 9^5 7^6 6^7 3^8

2^1 9^2 7^3 6^4 3^5 1^6 5^7 4^8

5^1 3^2 8^3 7^4 1^5 2^6 4^7 6^8 9^9

4^1 2^2 6^3 9^4 1^5 7^6 8^7 3^8 5^9

Total correct...........................

Digits Backwards

Practice Items 8 2, 7 1

2^1 5^2

6^1 3^2

5^1 7^2 4^3

2^1 5^2 9^3

7^1 2^2 9^3 6^4

8^1 4^2 9^3 3^4

4^1 1^2 3^3 5^4 7^5

9^1 7^2 8^3 5^4 2^5

1^1 6^2 5^3 2^4 9^5 8^6

3^1 6^2 7^3 1^4 9^5 4^6

8^1 5^2 9^3 2^4 3^5 4^6 2^7

4^1 5^2 7^3 9^4 2^5 8^6 1^7

6^1 9^2 1^3 6^4 3^5 2^6 5^7 8^8

3^1 1^2 7^3 9^4 5^5 4^6 8^7 2^8

Total Correct...................................

Total Score............................

Appendix B

Phoneme/grapheme task randomisation sheet

Working memory task randomisation sheet

Randomization for presentation of the four conditions in the phoneme/grapheme deletion task

(Tick of each order as you complete each subject)
Note: VO = visual orthographic
VP = visual phonological
AO = auditory orthographic
AP = auditory phonological

SS. IDENTIFICATION	ORDER	COMPLETED
	VO VP AO AP	
	AO AP VO VP	
	VO VP AP AO	
	AO AP VP VO	
	VP VO AO AP	
	AP AO VP VO	
	VP VO AP AO	
	AP AO VO VP	
	VO VP AO AP	
	AO AP VO VP	
	VO VP AP AO	
	AO AP VP VO	
	VP VO AO AP	
	AP AO VP VO	
	VP VO AP AO	
	AP AO VO VP	
	VO VP AO AP	
	AO AP VO VP	
	VO VP AP AO	
	AO AP VP VO	
	VP VO AO AP	
	AP AO VP VO	
	VP VO AP AO	
	AP AO VO VP	
	VO VP AO AP	
	AO AP VO VP	
	VO VP AP AO	
	AO AP VP VO	
	VP VO AO AP	
	AP AO VP VO	
	VP VO AP AO	
	AP AO VO VP	

Randomization for presentation of the six conditions in the working memory task

(Tick of each order as you complete each subject)

Note: RF= rhyming words forwards
RB = rhyming words backwards
NRF = non rhyming words forwards
NRB = non rhyming words backwards
DF = Digits forwards
DB = Digits backwards

SS. IDENTIFICATION	ORDER	COMPLETED
	RF RB NRF NRB DF DB	
	RF RB NRF NRB DB DF	
	RF RB NRB NRF DF DB	
	RF RB NRB NRF DB DF	
	RB RF NRF NRB DF DB	
	RB RF NRF NRB DB DF	
	RB RF NRB NRF DF DB	
	RB RF NRB NRF DB DF	
	RF RB DF DB NRF NRB	
	RF RB DB DF NRF NRB	
	RF RB DF DB NRB NRF	
	RF RB DB DF NRB NRF	
	RB RF DF DB NRF NRB	
	RB RF DB DF NRF NRB	
	RB RF DF DB NRB NRF	
	RB RF DB DF NRB NRF	
	NRF NRB RF RB DF DB	
	NRF NRB RF RB DB DF	
	NRF NRB RB RF DF DB	
	NRF NRB RB RF DB DF	
	NRB NRF RF RB DF DB	
	NRB NRF RF RB DB DF	
	NRB NRF RB RF DF DB	
	NRB NRF RB RF DB DF	
	NRF NRB DF DB RF RB	
	NRF NRB DB DF RF RB	
	NRF NRB DF DB RB RF	
	NRF NRB DB DF RB RF	
	NRB NRF DF DB RF RB	
	NRB NRF DB DF RF RB	
	NRB NRF DF DB RB RF	
	NRB NRF DB DF RB RF	
	DF DB NRF NRB RF RB	
	DB DF NRF NRB RF RB	
	DF DB NRF NRB RB RF	
	DB DF NRF NRB RB RF	

Appendix C

ANOVA, means and SNKs for correct response data

STATISTICA: ANOVA/MANOVA

Sonia's Masters data 1996

STAT. GENERAL MANOVA	Summary of all Effects; design: (sonia.sta) 1-GRADE, 2-MOD/V/A, 3-INST/O/P					
Effect	df Effect	MS Effect	df Error	MS Error	F	p-level
1	4*	176.0975*	95*	9.445263*	18.6440*	.000000*
2	1	.2500	95	1.879474	.1330	.716136
3	1	1.4400	95	5.177369	.2781	.599157
12	4	1.1750	95	1.879474	.6252	.645685
13	4	12.3025	95	5.177369	2.3762	.057388
23	1*	400.0000*	95*	2.613684*	153.0407*	.000000*
123	4*	9.3000*	95*	2.613684*	3.5582*	.009479*

Sonia

STAT. GENERAL MANOVA			Means (sonia.sta) F(4,95)=18.64; p<.0000
GRADE	MOD/V/A	INST/O/P	Depend. Var.1
2	....	....	3.525000
4	....	....	5.112500
6	....	....	6.362500
8	....	....	7.087500
10	....	....	6.887500

STAT. GENERAL MANOVA			Means (sonia.sta) F(4,95)=18.64; p<.0000
GRADE	MOD/V/A	INST/O/P	Depend. Var.1
2	....	....	3.525000
4	....	....	5.112500
6	....	....	6.362500
8	....	....	7.087500
10	....	....	6.887500

STAT. GENERAL MANOVA				Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests MAIN EFFECT: GRADE				
GRADE	MOD/V/A	INST/O/P		{1} 3.525000	{2} 5.112500	{3} 6.362500	{4} 7.087500	{5} 6.887500
2	....	....	{1}		.001663*	.000106*	.000118*	.000140*
4	....	....	{2}	.001663*		.011755*	.000679*	.001323*
6	....	....	{3}	.000106*	.011755*		.299438	.282795
8	....	....	{4}	.000118*	.000679*	.299438		.681714
10	....	....	{5}	.000140*	.001323*	.282795	.681714	

STAT. GENERAL MANOVA	INTERACTION: 2 x 3 (sonia.sta) 1-GRADE, 2-MOD/V/A, 3-INST/O/P				
Univar. Test	Sum of Squares	df	Mean Square	F	p-level
Effect	400.0000	1	400.0000	153.0407	.000000
Error	248.3000	95	2.6137		

STAT. GENERAL MANOVA			Means (sonia.sta) F(1,95)=153.04; p<.0000
GRADE	MOD/V/A	INST/O/P	Depend. Var.1
....	1	1	6.830000
....	1	2	4.710000
....	2	1	4.880000
....	2	2	6.760000

STATISTICA: ANOVA/MANOVA

Sonia

STAT. GENERAL MANOVA				Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests INTERACTION: 2 x 3			
GRADE	MOD/V/A	INST/O/P		{1} 6.830000	{2} 4.710000	{3} 4.880000	{4} 6.760000
....	1	1	{1}		.000140*	.000106*	.760270
....	1	2	{2}	.000140*		.459117	.000106*
....	2	1	{3}	.000106*	.459117		.000111*
....	2	2	{4}	.760270	.000106*	.000111*	

STAT. GENERAL MANOVA	INTERACTION: 1 x 2 x 3 (sonia.sta) 1-GRADE, 2-MOD/V/A, 3-INST/O/P				
Univar. Test	Sum of Squares	df	Mean Square	F	p-level
Effect	37.2000	4	9.300000	3.558196	.009479
Error	248.3000	95	2.613684		

STAT. GENERAL MANOVA			Means (sonia.sta) F(4,95)=3.56; p<.0095
GRADE	MOD/V/A	INST/O/P	Depend. Var.1
2	1	1	4.200000
2	1	2	2.650000
2	2	1	1.950000
2	2	2	5.300000
4	1	1	6.400000
4	1	2	3.800000
4	2	1	3.500000
4	2	2	6.750000
6	1	1	7.900000
6	1	2	4.950000
6	2	1	5.900000
6	2	2	6.700000
8	1	1	7.950000
8	1	2	5.850000
8	2	1	6.900000
8	2	2	7.650000
10	1	1	7.700000
10	1	2	6.300000
10	2	1	6.150000
10	2	2	7.400000

STAT. GENERAL MANOVA				Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests INTERACTION: 1 x 2 x 3				
GRADE	MOD/V/A	INST/O/P		{1} 4.200000	{2} 2.650000	{3} 1.950000	{4} 5.300000	{5} 6.400000
2	1	1	{1}		.016374*	.000368*	.085140	.001129*
2	1	2	{2}	.016374*		.174259	.000137*	.000172*
2	2	1	{3}	.000368*	.174259		.000121*	.000120*
2	2	2	{4}	.085140	.000137*	.000121*		.270472
4	1	1	{5}	.001129*	.000172*	.000120*	.270472	
4	1	2	{6}	.436057	.068282	.002745*	.021551*	.000186*
4	2	1	{7}	.361187	.099805	.008818*	.005947*	.000163*
4	2	2	{8}	.000260*	.000133*	.000134*	.098388	.773102
6	1	1	{9}	.000141*	.000170*	.000164*	.000249*	.077238
6	1	2	{10}	.145774	.000288*	.000123*	.495380	.078884
6	2	1	{11}	.010865*	.000121*	.000133*	.471858	.762350
6	2	2	{12}	.000256*	.000120*	.000133*	.100098	.558841
8	1	1	{13}	.000148*	.000164*	.000170*	.000228*	.073151
8	1	2	{14}	.009238*	.000121*	.000121*	.284829	.818547

STAT. GENERAL MANOVA				Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests INTERACTION: 1 x 2 x 3				
GRADE	MOD/V/A	INST/O/P		{1} 4.200000	{2} 2.650000	{3} 1.950000	{4} 5.300000	{5} 6.400000
8	2	1	{15}	.000205*	.000134*	.000141*	.056528	.762350
8	2	2	{16}	.000133*	.000148*	.000163*	.000781*	.151662
10	1	1	{17}	.000134*	.000163*	.000170*	.000634*	.156173
10	1	2	{18}	.001695*	.000159*	.000172*	.295639	.845446
10	2	1	{19}	.003323*	.000133*	.000159*	.349234	.876779
10	2	2	{20}	.000120*	.000141*	.000148*	.003341*	.295639

STAT. GENERAL MANOVA				Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests INTERACTION: 1 x 2 x 3				
GRADE	MOD/V/A	INST/O/P		{6} 3.800000	{7} 3.500000	{8} 6.750000	{9} 7.900000	{10} 4.950000
2	1	1	{1}	.436057	.361187	.000260*	.000141*	.145774
2	1	2	{2}	.068282	.099805	.000133*	.000170*	.000288*
2	2	1	{3}	.002745*	.008818*	.000134*	.000164*	.000123*
2	2	2	{4}	.021551*	.005947*	.098388	.000249*	.495380
4	1	1	{5}	.000186*	.000163*	.773102	.077238	.078884
4	1	2	{6}		.558841	.000175*	.000148*	.068282
4	2	1	{7}	.558841		.000120*	.000163*	.028187*
4	2	2	{8}	.000175*	.000120*		.225565	.018408*
6	1	1	{9}	.000148*	.000163*	.225565		.000140*
6	1	2	{10}	.068282	.028187*	.018408*	.000140*	
6	2	1	{11}	.001262*	.000295*	.559723	.007671*	.253166
6	2	2	{12}	.000163*	.000172*	.922397	.233121	.019922*
8	1	1	{13}	.000163*	.000170*	.233121	.922397	.000146*
8	1	2	{14}	.001219*	.000302*	.577763	.006517*	.188633
8	2	1	{15}	.000121*	.000133*	.769973	.295639	.008860*
8	2	2	{16}	.000134*	.000141*	.298928	.876779	.000162*
10	1	1	{17}	.000141*	.000148*	.347085	.696659	.000165*
10	1	2	{18}	.000218*	.000142*	.815160	.056528	.097683
10	2	1	{19}	.000373*	.000149*	.766388	.029779*	.139421
10	2	2	{20}	.000133*	.000134*	.414856	.762350	.000448*

STAT. GENERAL MANOVA				Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests INTERACTION: 1 x 2 x 3				
GRADE	MOD/V/A	INST/O/P		{11} 5.900000	{12} 6.700000	{13} 7.950000	{14} 5.850000	{15} 6.900000
2	1	1	{1}	.010865*	.000256*	.000148*	.009238*	.000205*
2	1	2	{2}	.000121*	.000120*	.000164*	.000121*	.000134*
2	2	1	{3}	.000133*	.000133*	.000170*	.000121*	.000141*
2	2	2	{4}	.471858	.100098	.000228*	.284829	.056528
4	1	1	{5}	.762350	.558841	.073151	.818547	.762350
4	1	2	{6}	.001262*	.000163*	.000163*	.001219*	.000121*
4	2	1	{7}	.000295*	.000172*	.000170*	.000302*	.000133*
4	2	2	{8}	.559723	.922397	.233121	.577763	.769973
6	1	1	{9}	.007671*	.233121	.922397	.006517*	.295639
6	1	2	{10}	.253166	.019922*	.000146*	.188633	.008860*
6	2	1	{11}		.523551	.006517*	.922397	.449369
6	2	2	{12}	.523551		.232436	.559723	.919256
8	1	1	{13}	.006517*	.232436		.005450*	.320557
8	1	2	{14}	.922397	.559723	.005450*		.452182
8	2	1	{15}	.449369	.919256	.320557	.452182	
8	2	2	{16}	.024679*	.347085	.935927	.022281*	.311452
10	1	1	{17}	.022281*	.375382	.876779	.019595*	.403632
10	1	2	{18}	.714782	.714782	.051854	.815160	.766388
10	2	1	{19}	.626089	.705151	.026387*	.827589	.685942
10	2	2	{20}	.077238	.521737	.818547	.073151	.330670

Sonia

STAT. GENERAL MANOVA				Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests INTERACTION: 1 x 2 x 3				
GRADE	MOD/V/A	INST/O/P		{16} 7.650000	{17} 7.700000	{18} 6.300000	{19} 6.150000	{20} 7.400000
2	1	1	{1}	.000133*	.000134*	.001695*	.003323*	.000120*
2	1	2	{2}	.000148*	.000163*	.000159*	.000133*	.000141*
2	2	1	{3}	.000163*	.000170*	.000172*	.000159*	.000148*
2	2	2	{4}	.000781*	.000634*	.295639	.349234	.003341*
4	1	1	{5}	.151662	.156173	.845446	.876779	.295639
4	1	2	{6}	.000134*	.000141*	.000218*	.000373*	.000133*
4	2	1	{7}	.000141*	.000148*	.000142*	.000149*	.000134*
4	2	2	{8}	.298928	.347085	.815160	.766388	.414856
6	1	1	{9}	.876779	.696659	.056528	.029779*	.762350
6	1	2	{10}	.000162*	.000165*	.097683	.139421	.000448*
6	2	1	{11}	.024679*	.022281*	.714782	.626089	.077238
6	2	2	{12}	.347085	.375382	.714782	.705151	.521737
8	1	1	{13}	.935927	.876779	.051854	.026387*	.818547
8	1	2	{14}	.022281*	.019595*	.815160	.827589	.073151
8	2	1	{15}	.311452	.403632	.766388	.685942	.330670
8	2	2	{16}		.922397	.125700	.077238	.626089
10	1	1	{17}	.922397		.124043	.073151	.827589
10	1	2	{18}	.125700	.124043		.769973	.270472
10	2	1	{19}	.077238	.073151	.769973		.191924
10	2	2	{20}	.626089	.827589	.270472	.191924	

data file: SONIA.STA [100 cases with 53 variables]

VARIABLES:
7: VMORO -9999
11: VMPRP -9999
14: AMORO -9999
18: AMPRP -9999
4: GRADE -9999
6: SEX -9999

INDEPENDENT VARIABLES (between-groups factors):

GRADE Number of Levels: 5 Codes: level 1: 2
level 2: 4
level 3: 6
level 4: 8
level 5: 10
SEX Number of Levels: 2 Codes: level 1: 1
level 2: 2

DESIGN: 4 - way ANOVA , fixed effects
DEPENDENT: 1 variable (Repeated Measure)
BETWEEN: 1-GRADE (5): 2 4 6 8 10
2-SEX (2): 1 2
WITHIN: 3-MOD/V/A(2) x 4-INST/O/P(2)

STATISTICA: ANOVA/MANOVA

Sonia's consistent inconsistent analysis on correct data

STAT. GENERAL MANOVA	Summary of all Effects; design: (sonia.sta) 1-GRADE, 2-CON/INC					
Effect	df Effect	MS Effect	df Error	MS Error	F	p-level
1	4*	88.0488*	95*	4.722631*	18.6440*	.000000*
2	1*	200.0000*	95*	1.306842*	153.0407*	.000000*
12	4*	4.6500*	95*	1.306842*	3.5582*	.009479*

DESIGN: 2 - way ANOVA , fixed effects
DEPENDENT: 1 variable (Repeated Measure)
BETWEEN: 1-GRADE (5): 2 4 6 8 10
WITHIN: 2-CON/INC(2)

STAT. GENERAL MANOVA	MAIN EFFECT: GRADE (sonia.sta) 1-GRADE, 2-CON/INC				
Univar. Test	Sum of Squares	df	Mean Square	F	p-level
Effect	352.1950	4	88.04875	18.64400	.000000
Error	448.6500	95	4.72263		

STAT. GENERAL MANOVA		Means (sonia.sta) F(4,95)=18.64; p<.0000
GRADE	CON/INC	Depend. Var.1
2	....	3.525000
4	....	5.112500
6	....	6.362500
8	....	7.087500
10	....	6.887500

STAT. GENERAL MANOVA			Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests MAIN EFFECT: GRADE				
GRADE	CON/INC		{1} 3.525000	{2} 5.112500	{3} 6.362500	{4} 7.087500	{5} 6.887500
2	....	{1}		.001663*	.000106*	.000118*	.000140*
4	....	{2}	.001663*		.011755*	.000679*	.001323*
6	....	{3}	.000106*	.011755*		.299438	.282795
8	....	{4}	.000118*	.000679*	.299438		.681714
10	....	{5}	.000140*	.001323*	.282795	.681714	

STAT. GENERAL MANOVA	Means (sonia.sta) 2 Variables		
GRADE	VAR33	VAR34	Valid N
G_1:2	4.750000	2.300000	20
G_2:4	6.575000	3.650000	20
G_3:6	7.300000	5.425000	20
G_4:8	7.800000	6.375000	20
G_5:10	7.550000	6.225000	20
All Groups	6.795000	4.795000	100

STATISTICA: ANOVA/MANOVA

Sonia's consistent inconsistent analysis on correct data

STAT. GENERAL MANOVA	Standard Deviations (sonia.sta) 2 Variables		
GRADE	VAR33	VAR34	Valid N
G_1:2	1.342621	1.427180	20
G_2:4	1.280162	2.084403	20
G_3:6	1.417930	1.934962	20
G_4:8	1.056309	2.321949	20
G_5:10	1.580306	2.359053	20
All Groups	1.721954	2.562447	100

STAT. GENERAL MANOVA	MAIN EFFECT: CON/INC (sonia.sta) 1-GRADE, 2-CON/INC				
Univar. Test	Sum of Squares	df	Mean Square	F	p-level
Effect	200.0000	1	200.0000	153.0407	.000000
Error	124.1500	95	1.3068		

STAT. GENERAL MANOVA		Means (sonia.sta) F(1,95)=153.04; p<.0000
GRADE	CON/INC	Depend. Var.1
....	1	6.795000
....	2	4.795000

STAT. GENERAL MANOVA	INTERACTION: 1 x 2 (sonia.sta) 1-GRADE, 2-CON/INC				
Univar. Test	Sum of Squares	df	Mean Square	F	p-level
Effect	18.6000	4	4.650000	3.558196	.009479
Error	124.1500	95	1.306842		

STAT. GENERAL MANOVA		Means (sonia.sta) F(4,95)=3.56; p<.0095
GRADE	CON/INC	Depend. Var.1
2	1	4.750000
2	2	2.300000
4	1	6.575000
4	2	3.650000
6	1	7.300000
6	2	5.425000
8	1	7.800000
8	2	6.375000
10	1	7.550000
10	2	6.225000

Sonia's consistent inconsistent analysis on correct data

STAT. GENERAL MANOVA — Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests INTERACTION: 1 x 2

GRADE	CON/INC		{1} 4.750000	{2} 2.300000	{3} 6.575000	{4} 3.650000	{5} 7.300000	{6} 5.425000
2	1	{1}		.000106*	.000135*	.003167*	.000122*	.065061
2	2	{2}	.000106*		.000121*	.000422*	.000121*	.000140*
4	1	{3}	.000135*	.000121*		.000122*	.047841*	.010598*
4	2	{4}	.003167*	.000422*	.000122*		.000121*	.000115*
6	1	{5}	.000122*	.000121*	.047841*	.000121*		.000127*
6	2	{6}	.065061	.000140*	.010598*	.000115*	.000127*	
8	1	{7}	.000121*	.000159*	.005654*	.000133*	.353868	.000121*
8	2	{8}	.000243*	.000122*	.581512	.000118*	.032203*	.026928*
10	1	{9}	.000121*	.000133*	.022441*	.000121*	.491024	.000123*
10	2	{10}	.000367*	.000118*	.598776	.000140*	.019295*	.029385*

STAT. GENERAL MANOVA — Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests INTERACTION: 1 x 2

GRADE	CON/INC		{7} 7.800000	{8} 6.375000	{9} 7.550000	{10} 6.225000
2	1	{1}	.000121*	.000243*	.000121*	.000367*
2	2	{2}	.000159*	.000122*	.000133*	.000118*
4	1	{3}	.005654*	.581512	.022441*	.598776
4	2	{4}	.000133*	.000118*	.000121*	.000140*
6	1	{5}	.353868	.032203*	.491024	.019295*
6	2	{6}	.000121*	.026928*	.000123*	.029385*
8	1	{7}		.001552*	.491024	.000579*
8	2	{8}	.001552*		.008621*	.679265
10	1	{9}	.491024	.008621*		.003756*
10	2	{10}	.000579*	.679265	.003756*	

data file: SONIA.STA [100 cases with 53 variables]

VARIABLES:
36: CONSCOR -9999 =(v7+v18)/2
37: INCONCOR -9999 =(v11+v14)/2
4: GRADE -9999

INDEPENDENT VARIABLES (between-groups factors):

GRADE Number of Levels: 5 Codes: level 1: 2
level 2: 4
level 3: 6
level 4: 8
level 5: 10

DESIGN: 2 - way ANOVA , fixed effects
DEPENDENT: 1 variable (Repeated Measure)
BETWEEN: 1-GRADE (5): 2 4 6 8 10
WITHIN: 2-CON/INC(2)

data file: SONIA.STA [100 cases with 53 variables]

VARIABLES:
7: VMORO -9999
11: VMPRP -9999
14: AMORO -9999
18: AMPRP -9999
4: GRADE -9999

Appendix D

ANOVA, means and SNKs for spelling/reading data

STAT. GENERAL MANOVA	Summary of all Effects; design: (sonia.sta) 1-GRADE, 2-SP/RE					
Effect	df Effect	MS Effect	df Error	MS Error	F	p-level
1	4*	626.1350*	94*	36.37046*	17.21548*	.000000*
2	1*	238.5634*	94*	3.76347*	63.38928*	.000000*
12	4*	33.1267*	94*	3.76347*	8.80219*	.000004*

```
    DESIGN: 2 - way ANOVA          , fixed effects
 DEPENDENT: 1 variable (Repeated Measure)
   BETWEEN: 1-GRADE   ( 5):     2     4     6     8     10
    WITHIN: 2-SP/RE(2)
```

STAT. GENERAL MANOVA	MAIN EFFECT: GRADE (sonia.sta) 1-GRADE, 2-SP/RE				
Univar. Test	Sum of Squares	df	Mean Square	F	p-level
Effect	2504.540	4	626.1350	17.21548	.000000
Error	3418.824	94	36.3705		

STAT. GENERAL MANOVA		Means (sonia.sta) F(4,94)=17.22; p<.0000
GRADE	SP/RE	Depend. Var.1
2	....	24.25000
4	....	28.27500
6	....	33.62500
8	....	33.02632
10	....	32.25000

STAT. GENERAL MANOVA			Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests MAIN EFFECT: GRADE				
GRADE	SP/RE		{1} 24.25000	{2} 28.27500	{3} 33.62500	{4} 33.02632	{5} 32.25000
2	....	{1}		.003920*	.000116*	.000139*	.000104*
4	....	{2}	.003920*		.000972*	.002100*	.004355*
6	....	{3}	.000116*	.000972*		.659893	.569808
8	....	{4}	.000139*	.002100*	.659893		.568355
10	....	{5}	.000104*	.004355*	.569808	.568355	

STAT. GENERAL MANOVA	MAIN EFFECT: SP/RE (sonia.sta) 1-GRADE, 2-SP/RE				
Univar. Test	Sum of Squares	df	Mean Square	F	p-level
Effect	238.5634	1	238.5634	63.38928	.000000
Error	353.7658	94	3.7635		

STAT. GENERAL MANOVA		Means (unweighted) (sonia.sta) F(1,94)=63.39; p<.0000
GRADE	SP/RE	Depend. Var.1
....	1	29.18737
....	2	31.38316

STAT. GENERAL MANOVA	INTERACTION: 1 x 2 (sonia.sta) 1-GRADE, 2-SP/RE				
Univar. Test	Sum of Squares	df	Mean Square	F	p-level
Effect	132.5069	4	33.12674	8.802188	.000004
Error	353.7658	94	3.76347		

STAT. GENERAL MANOVA		Means (sonia.sta) F(4,94)=8.80; p<.0000
GRADE	SP/RE	Depend. Var.1
2	1	21.75000
2	2	26.75000
4	1	26.80000
4	2	29.75000
6	1	33.25000
6	2	34.00000
8	1	32.73684
8	2	33.31579
10	1	31.40000
10	2	33.10000

STAT. GENERAL MANOVA			Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests INTERACTION: 1 x 2						
GRADE	SP/RE		{1} 21.75000	{2} 26.75000	{3} 26.80000	{4} 29.75000	{5} 33.25000	{6} 34.00000	{7} 32.73684
2	1	{1}		.000111*	.000104*	.000139*	.000115*	.000157*	.000120*
2	2	{2}	.000111*		.935641	.000115*	.000119*	.000131*	.000116*
4	1	{3}	.000104*	.935641		.000116*	.000120*	.000115*	.000139*
4	2	{4}	.000139*	.000115*	.000116*		.000117*	.000119*	.000116*
6	1	{5}	.000115*	.000119*	.000120*	.000117*		.446720	.684178
6	2	{6}	.000157*	.000131*	.000115*	.000119*	.446720		.251611
8	1	{7}	.000120*	.000116*	.000139*	.000116*	.684178	.251611	
8	2	{8}	.000131*	.000115*	.000119*	.000121*	.915367	.270132	.784129
10	1	{9}	.000116*	.000139*	.000104*	.008912*	.017962*	.000895*	.032790*
10	2	{10}	.000119*	.000120*	.000116*	.000140*	.808456	.466108	.557468

STAT. GENERAL MANOVA			Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests INTERACTION: 1 x 2		
GRADE	SP/RE		{8} 33.31579	{9} 31.40000	{10} 33.10000
2	1	{1}	.000131*	.000116*	.000119*
2	2	{2}	.000115*	.000139*	.000120*
4	1	{3}	.000119*	.000104*	.000116*
4	2	{4}	.000121*	.008912*	.000140*
6	1	{5}	.915367	.017962*	.808456
6	2	{6}	.270132	.000895*	.466108
8	1	{7}	.784129	.032790*	.557468
8	2	{8}		.020711*	.934878
10	1	{9}	.020711*		.019156*
10	2	{10}	.934878	.019156*	

Appendix E

MANOVA, means and SNKs for working memory span data

STAT. GENERAL MANOVA	Summary of all Effects; design: (sonia.sta) 1-GRADE, 2-R/W/D, 3-F/B					
Effect	df Effect	MS Effect	df Error	MS Error	F	p-level
1	4*	12.2794*	94*	1.379148*	8.9036*	.000004*
2	2*	51.7040*	188*	.576712*	89.6529*	.000000*
3	1*	211.5681*	94*	.457759*	462.1819*	0.000000*
12	8	.5710	188	.576712	.9901	.445157
13	4	.4102	94	.457759	.8960	.469633
23	2*	8.5324*	188*	.542922*	15.7156*	.000000*
123	8	1.0351	188	.542922	1.9066	.061185

STAT. GENERAL MANOVA	MAIN EFFECT: GRADE (sonia.sta) 1-GRADE, 2-R/W/D, 3-F/B				
Univar. Test	Sum of Squares	df	Mean Square	F	p-level
Effect	49.1177	4	12.27942	8.903625	.000004
Error	129.6399	94	1.37915		

STAT. GENERAL MANOVA			Means (sonia.sta) F(4,94)=8.90; p<.0000
GRADE	R/W/D	F/B	Depend. Var.1
2	....	....	2.975000
4	....	....	3.166667
6	....	....	3.575000
8	....	....	3.649123
10	....	....	3.691667

STAT. GENERAL MANOVA				Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests MAIN EFFECT: GRADE				
GRADE	R/W/D	F/B		{1} 2.975000	{2} 3.166667	{3} 3.575000	{4} 3.649123	{5} 3.691667
2	....	....	{1}		.211737	.000548*	.000276*	.000191*
4	....	....	{2}	.211737		.008824*	.005957*	.004768*
6	....	....	{3}	.000548*	.008824*		.627974	.725078
8	....	....	{4}	.000276*	.005957*	.627974		.780860
10	....	....	{5}	.000191*	.004768*	.725078	.780860	

STAT. GENERAL MANOVA	MAIN EFFECT: R/W/D (sonia.sta) 1-GRADE, 2-R/W/D, 3-F/B				
Univar. Test	Sum of Squares	df	Mean Square	F	p-level
Effect	103.4079	2	51.70396	89.65295	.000000
Error	108.4219	188	.57671		

STAT. GENERAL MANOVA	MAIN EFFECT: R/W/D (sonia.sta) 1-GRADE, 2-R/W/D, 3-F/B	
Test	Value	p-level
Wilks' Lambda	.41037	
Rao R Form 2 (2, 93)	66.81130	.000000
Pillai-Bartlett Trace	.58963	

STAT. GENERAL MANOVA	MAIN EFFECT: R/W/D (sonia.sta) 1-GRADE, 2-R/W/D, 3-F/B	
Test	Value	p-level
V (2,93)	66.81130	.000000

STAT. GENERAL MANOVA			Means (unweighted) (sonia.sta) Rao R (2,93)=66.81; p<.0000
GRADE	R/W/D	F/B	Depend. Var.1
....	1	....	2.961316
....	2	....	3.306053
....	3	....	3.967105

STAT. GENERAL MANOVA				Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests MAIN EFFECT: R/W/D		
GRADE	R/W/D	F/B		{1} 2.961316	{2} 3.306053	{3} 3.967105
....	1	....	{1}		.000015 *	.000022 *
....	2	....	{2}	.000015 *		.000009 *
....	3	....	{3}	.000022 *	.000009 *	

STAT. GENERAL MANOVA	MAIN EFFECT: F/B (sonia.sta) 1-GRADE, 2-R/W/D, 3-F/B				
Univar. Test	Sum of Squares	df	Mean Square	F	p-level
Effect	211.5681	1	211.5681	462.1819	0.00
Error	43.0294	94	.4578		

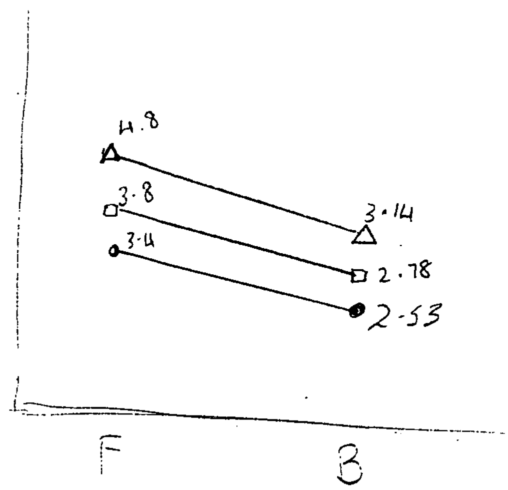
STAT. GENERAL MANOVA			Means (unweighted) (sonia.sta) F(1,94)=462.18; p<0.000
GRADE	R/W/D	F/B	Depend. Var.1
....	....	1	4.008421
....	....	2	2.814561

STAT. GENERAL MANOVA	INTERACTION: 2 x 3 (sonia.sta) 1-GRADE, 2-R/W/D, 3-F/B	
Test	Value	p-level
Wilks' Lambda Rao R Form 2 (2, 93)	.78853 12.47083	 .000016
Pillai-Bartlett Trace V (2,93)	.21147 12.47083	 .000016

STAT. GENERAL MANOVA			Means (unweighted) (sonia.sta) Rao R (2,93)=12.47; p<.0000
GRADE	R/W/D	F/B	Depend. Var.1
....	1	1	3.397368
....	1	2	2.525263
....	2	1	3.829474
....	2	2	2.782632
....	3	1	4.798421
....	3	2	3.135789

STAT. GENERAL MANOVA				Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests INTERACTION: 2 x 3					
GRADE	R/W/D	F/B		{1} 3.397368	{2} 2.525263	{3} 3.829474	{4} 2.782632	{5} 4.798421	{6} 3.135789
....	1	1	{1}		.000008*	.000045*	.000022*	.000022*	.012511*
....	1	2	{2}	.000008*		.000017*	.014002*	.000020*	.000022*
....	2	1	{3}	.000045*	.000017*		.000008*	.000009*	.000022*
....	2	2	{4}	.000022*	.014002*	.000008*		.000017*	.000751*
....	3	1	{5}	.000022*	.000020*	.000009*	.000017*		.000008*
....	3	2	{6}	.012511*	.000022*	.000022*	.000751*	.000008*	

STAT. GENERAL MANOVA	INTERACTION: 1 x 2 x 3 (sonia.sta) 1-GRADE, 2-R/W/D, 3-F/B				
Univar. Test	Sum of Squares	df	Mean Square	F	p-level
Effect	8.2809	8	1.035109	1.906552	.061185
Error	102.0693	188	.542922		



STAT. GENERAL MANOVA	INTERACTION: 1 x 2 x 3 (sonia.sta) 1-GRADE, 2-R/W/D, 3-F/B	
Test	Value	p-level
Wilks' Lambda	.841208	
Rao R Form 1 (8,186)	2.099610	.037795
Pillai-Bartlett Trace	.163168	
V (8,188)	2.087538	.038910

STAT. GENERAL MANOVA			Means (sonia.sta) Rao R (8,186)=2.10; p<.0378
GRADE	R/W/D	F/B	Depend. Var.1
2	1	1	2.850000
2	1	2	2.300000
2	2	1	3.550000
2	2	2	2.150000
2	3	1	4.400000
2	3	2	2.600000
4	1	1	3.100000
4	1	2	2.300000
4	2	1	3.900000
4	2	2	2.500000
4	3	1	4.400000
4	3	2	2.800000
6	1	1	3.500000

STAT. GENERAL MANOVA			Means (sonia.sta) Rao R (8,186)=2.10; p<.0378
GRADE	R/W/D	F/B	Depend. Var.1
6	1	2	2.800000
6	2	1	3.650000
6	2	2	2.900000
6	3	1	5.200000
6	3	2	3.400000
8	1	1	3.736842
8	1	2	2.526316
8	2	1	3.947368
8	2	2	3.263158
8	3	1	4.842105
8	3	2	3.578947
10	1	1	3.800000
10	1	2	2.700000
10	2	1	4.100000
10	2	2	3.100000
10	3	1	5.150000
10	3	2	3.300000

STAT. GENERAL MANOVA — Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests INTERACTION: 1 x 2 x 3

GRADE	R/W/D	F/B		{1} 2.850000	{2} 2.300000	{3} 3.550000	{4} 2.150000	{5} 4.400000	{6} 2.600000
4	1	1	{7}	.534422	.026717*	.466076	.002932*	.000029*	.332104

STAT. GENERAL MANOVA — Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests INTERACTION: 1 x 2 x 3

GRADE	R/W/D	F/B		{7} 3.100000	{8} 2.300000	{9} 3.900000	{10} 2.500000	{11} 4.400000	{12} 2.800000
4	1	1	{7}		.022433*	.031265*	.203003	.000032*	.703111

STAT. GENERAL MANOVA — Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests INTERACTION: 1 x 2 x 3

GRADE	R/W/D	F/B		{13} 3.500000	{14} 2.800000	{15} 3.650000	{16} 2.900000	{17} 5.200000	{18} 3.400000
4	1	1	{7}	.526580	.575202	.313180	.393192	.000039*	.703111

STAT. GENERAL MANOVA — Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests INTERACTION: 1 x 2 x 3

GRADE	R/W/D	F/B		{19} 3.736842	{20} 2.526316	{21} 3.947368	{22} 3.263158	{23} 4.842105	{24} 3.578947
4	1	1	{7}	.165906	.217728	.018142*	.765494	.000033*	.451408

STAT. GENERAL MANOVA — Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests INTERACTION: 1 x 2 x 3

GRADE	R/W/D	F/B		{25} 3.800000	{26} 2.700000	{27} 4.100000	{28} 3.100000	{29} 5.150000	{30} 3.300000
4	1	1	{7}	.097133	.526580	.001613*	1.000000	.000036*	.828520

STAT.
GENERAL
MANOVA

Newman-Keuls test; Var.1 (sonia.sta)
Probabilities for Post Hoc Tests
INTERACTION: 1 x 2 x 3

GRADE	R/W/D	F/B		{1} 2.850000	{2} 2.300000	{3} 3.550000	{4} 2.150000	{5} 4.400000	{6} 2.600000
2	1	1	{1}		.313180	.069422	.082987	.000033*	.823346
2	1	2	{2}	.313180		.000043*	.521920	.000019*	.703111
2	2	1	{3}	.069422	.000043*		.000036*	.008698*	.003427*
2	2	2	{4}	.082987	.521920	.000036*		.000020*	.389002
2	3	1	{5}	.000033*	.000019*	.008698*	.000020*		.000046*
2	3	2	{6}	.823346	.703111	.003427*	.389002	.000046*	
4	1	1	{7}	.534422	.026717*	.466076	.002932*	.000029*	.332104
4	1	2	{8}	.267482	1.000000	.000039*	.797794	.000018*	.575202
4	2	1	{9}	.000631*	.000015*	.668006	.000016*	.142154	.000039*
4	2	2	{10}	.748459	.669423	.000724*	.440935	.000016*	.904430
4	3	1	{11}	.000036*	.000020*	.010654*	.000022*	1.000000	.000015*
4	3	2	{12}	.975203	.332104	.052599	.101260	.000039*	.669423
6	1	1	{13}	.101260	.000061*	.830980	.000033*	.004787*	.006817*
6	1	2	{14}	.830980	.392378	.044505*	.122724	.000036*	.828520
6	2	1	{15}	.026717*	.000040*	.904430	.000043*	.023128*	.000724*
6	2	2	{16}	.830980	.236097	.101260	.052599	.000029*	.795704
6	3	1	{17}	.000046*	.000024*	.000020*	.000025*	.005762*	.000019*
6	3	2	{18}	.221174	.000278*	.797794	.000039*	.001019*	.026717*
8	1	1	{19}	.008439*	.000043*	.855513	.000046*	.052671	.000160*
8	1	2	{20}	.738029	.768690	.001039*	.493070	.000015*	.753090
8	2	1	{21}	.000293*	.000016*	.618433	.000018*	.129606	.000040*
8	2	2	{22}	.394865	.002725*	.737015	.000189*	.000106*	.106306
8	3	1	{23}	.000039*	.000022*	.000016*	.000022*	.142276	.000016*
8	3	2	{24}	.058315	.000041*	.901654	.000039*	.010791*	.002384*
10	1	1	{25}	.003427*	.000046*	.823346	.000015*	.077625	.000068*
10	1	2	{26}	.918920	.526580	.015031*	.221174	.000043*	.669433
10	2	1	{27}	.000039*	.000018*	.267482	.000019*	.200272	.000043*
10	2	2	{28}	.709482	.031265*	.389002	.003427*	.000025*	.392378
10	3	1	{29}	.000043*	.000022*	.000017*	.000024*	.007465*	.000018*
10	3	2	{30}	.389002	.001613*	.709482	.000112*	.000178*	.082987

STAT.
GENERAL
MANOVA

Newman-Keuls test; Var.1 (sonia.sta)
Probabilities for Post Hoc Tests
INTERACTION: 1 x 2 x 3

GRADE	R/W/D	F/B		{7} 3.100000	{8} 2.300000	{9} 3.900000	{10} 2.500000	{11} 4.400000	{12} 2.800000
2	1	1	{1}	.534422	.267482	.000631*	.748459	.000036*	.975203
2	1	2	{2}	.026717*	1.000000	.000015*	.669423	.000020*	.332104
2	2	1	{3}	.466076	.000039*	.668006	.000724*	.010654*	.052599
2	2	2	{4}	.002932*	.797794	.000016*	.440935	.000022*	.101260
2	3	1	{5}	.000029*	.000018*	.142154	.000016*	1.000000	.000039*
2	3	2	{6}	.332104	.575202	.000039*	.904430	.000015*	.669423
4	1	1	{7}		.022433*	.031265*	.203003	.000032*	.703111
4	1	2	{8}	.022433*		.000046*	.393192	.000019*	.269328
4	2	1	{9}	.031265*	.000046*		.000043*	.205339	.000316*
4	2	2	{10}	.203003	.393192	.000043*		.000018*	.703111
4	3	1	{11}	.000032*	.000019*	.205339	.000018*		.000043*
4	3	2	{12}	.703111	.269328	.000316*	.703111	.000043*	
6	1	1	{13}	.526580	.000054*	.610842	.001613*	.005764*	.082987
6	1	2	{14}	.575202	.332104	.000278*	.795704	.000039*	1.000000
6	2	1	{15}	.313180	.000036*	.709482	.000143*	.029712*	.017435*
6	2	2	{16}	.393192	.203003	.001393*	.682285	.000033*	.973889
6	3	1	{17}	.000039*	.000022*	.000033*	.000022*	.003571*	.000016*
6	3	2	{18}	.703111	.000243*	.392378	.007942*	.001189*	.203003
8	1	1	{19}	.165906	.000039*	.765494	.000052*	.069433	.004954*
8	1	2	{20}	.217728	.598289	.000040*	.910555	.000016*	.646828
8	2	1	{21}	.018142*	.000015*	.839752	.000046*	.214413	.000150*
8	2	2	{22}	.765494	.002330*	.165906	.044278*	.000123*	.429142
8	3	1	{23}	.000033*	.000020*	.000827*	.000019*	.059099	.000046*
8	3	2	{24}	.451408	.000038*	.646557	.000473*	.013534*	.041776*
10	1	1	{25}	.097133	.000043*	.669433	.000043*	.106879	.001847*
10	1	2	{26}	.526580	.429095	.000068*	.828520	.000046*	.669433
10	2	1	{27}	.001613*	.000016*	.669423	.000015*	.406029	.000039*
10	2	2	{28}	1.000000	.026717*	.026717*	.236097	.000029*	.795704
10	3	1	{29}	.000036*	.000022*	.000027*	.000020*	.003909*	.000015*
10	3	2	{30}	.828520	.001393*	.203003	.031265*	.000210*	.392378

STAT. GENERAL MANOVA — Newman-Keuls test; Var.1 (sonia.sta)
Probabilities for Post Hoc Tests
INTERACTION: 1 x 2 x 3

GRADE	R/W/D	F/B		{13} 3.500000	{14} 2.800000	{15} 3.650000	{16} 2.900000	{17} 5.200000	{18} 3.400000
2	1	1	{1}	.101260	.830980	.026717*	.830980	.000046*	.221174
2	1	2	{2}	.000061*	.392378	.000040*	.236097	.000024*	.000278*
2	2	1	{3}	.830980	.044505*	.904430	.101260	.000020*	.797794
2	2	2	{4}	.000033*	.122724	.000043*	.052599	.000025*	.000039*
2	3	1	{5}	.004787*	.000036*	.023128*	.000029*	.005762*	.001019*
2	3	2	{6}	.006817*	.828520	.000724*	.795704	.000019*	.026717*
4	1	1	{7}	.526580	.575202	.313180	.393192	.000039*	.703111
4	1	2	{8}	.000054*	.332104	.000036*	.203003	.000022*	.000243*
4	2	1	{9}	.610842	.000278*	.709482	.001393*	.000033*	.392378
4	2	2	{10}	.001613*	.795704	.000143*	.682285	.000022*	.007942*
4	3	1	{11}	.005764*	.000039*	.029712*	.000033*	.003571*	.001189*
4	3	2	{12}	.082987	1.000000	.017435*	.973889	.000016*	.203003
6	1	1	{13}		.069422	.918920	.137945	.000023*	.669433
6	1	2	{14}	.069422		.015031*	.904430	.000015*	.170151
6	2	1	{15}	.918920	.015031*		.044505*	.000015*	.823346
6	2	2	{16}	.137945	.904430	.044505*		.000043*	.269328
6	3	1	{17}	.000023*	.000015*	.000015*	.000043*		.000026*
6	3	2	{18}	.669433	.170151	.823346	.269328	.000026*	
8	1	1	{19}	.850381	.004296*	.710833	.015606*	.000012*	.703661
8	1	2	{20}	.002265*	.769460	.000203*	.685388	.000020*	.010408*
8	2	1	{21}	.543945	.000133*	.709995	.000664*	.000027*	.319771
8	2	2	{22}	.742905	.355345	.648541	.407322	.000033*	.828583
8	3	1	{23}	.000018*	.000043*	.000022*	.000036*	.277761	.000020*
8	3	2	{24}	.939304	.035805*	.761636	.088941	.000017*	.870661
10	1	1	{25}	.795704	.001613*	.797794	.006817*	.000010*	.610842
10	1	2	{26}	.026717*	.904430	.003955*	.913523	.000018*	.082987
10	2	1	{27}	.203003	.000036*	.389002	.000054*	.000057*	.082987
10	2	2	{28}	.429095	.703111	.267482	.669423	.000036*	.575202
10	3	1	{29}	.000020*	.000046*	.000012*	.000039*	.830980	.000023*
10	3	2	{30}	.669423	.332104	.668006	.429095	.000029*	.669433

STAT. GENERAL MANOVA — Newman-Keuls test; Var.1 (sonia.sta)
Probabilities for Post Hoc Tests
INTERACTION: 1 x 2 x 3

GRADE	R/W/D	F/B		{19} 3.736842	{20} 2.526316	{21} 3.947368	{22} 3.263158	{23} 4.842105	{24} 3.578947
2	1	1	{1}	.008439*	.738029	.000293*	.394865	.000039*	.058315
2	1	2	{2}	.000043*	.768690	.000016*	.002725*	.000022*	.000041*
2	2	1	{3}	.855513	.001039*	.618433	.737015	.000016*	.901654
2	2	2	{4}	.000046*	.493070	.000018*	.000189*	.000022*	.000039*
2	3	1	{5}	.052671	.000015*	.129606	.000106*	.142276	.010791*
2	3	2	{6}	.000160*	.753090	.000040*	.106306	.000016*	.002384*
4	1	1	{7}	.165906	.217728	.018142*	.765494	.000033*	.451408
4	1	2	{8}	.000039*	.598289	.000015*	.002330*	.000020*	.000038*
4	2	1	{9}	.765494	.000040*	.839752	.165906	.000827*	.646557
4	2	2	{10}	.000052*	.910555	.000046*	.044278*	.000019*	.000473*
4	3	1	{11}	.069433	.000016*	.214413	.000123*	.059099	.013534*
4	3	2	{12}	.004954*	.646828	.000150*	.429142	.000046*	.041776*
6	1	1	{13}	.850381	.002265*	.543945	.742905	.000018*	.939304
6	1	2	{14}	.004296*	.769460	.000133*	.355345	.000043*	.035805*
6	2	1	{15}	.710833	.000203*	.709995	.648541	.000022*	.761636
6	2	2	{16}	.015606*	.685388	.000664*	.407322	.000036*	.088941
6	3	1	{17}	.000012*	.000020*	.000027*	.000033*	.277761	.000017*
6	3	2	{18}	.703661	.010408*	.319771	.828583	.000020*	.870661
8	1	1	{19}		.000060*	.805460	.466581	.000092*	.778577
8	1	2	{20}	.000060*		.000043*	.052758	.000018*	.000689*
8	2	1	{21}	.805460	.000043*		.116260	.001268*	.616546
8	2	2	{22}	.466581	.052758	.116260		.000026*	.757906
8	3	1	{23}	.000092*	.000018*	.001268*	.000026*		.000015*
8	3	2	{24}	.778577	.000689*	.616546	.757906	.000015*	
10	1	1	{25}	.787457	.000042*	.804081	.346856	.000193*	.781217
10	1	2	{26}	.000930*	.738757	.000048*	.239037	.000015*	.011137*
10	2	1	{27}	.529502	.000046*	.514645	.018343*	.008351*	.282146
10	2	2	{28}	.141029	.257309	.015645*	.486077	.000029*	.386240
10	3	1	{29}	.000010*	.000019*	.000024*	.000029*	.188685	.000015*
10	3	2	{30}	.503790	.038458*	.148935	.875029	.000023*	.756675

STAT. GENERAL MANOVA				Newman-Keuls test; Var.1 (sonia.sta) Probabilities for Post Hoc Tests INTERACTION: 1 x 2 x 3					
GRADE	R/W/D	F/B		{25} 3.800000	{26} 2.700000	{27} 4.100000	{28} 3.100000	{29} 5.150000	{30} 3.300000
2	1	1	{1}	.003427*	.918920	.000039*	.709482	.000043*	.389002
2	1	2	{2}	.000046*	.526580	.000018*	.031265*	.000022*	.001613*
2	2	1	{3}	.823346	.015031*	.267482	.389002	.000017*	.709482
2	2	2	{4}	.000015*	.221174	.000019*	.003427*	.000024*	.000112*
2	3	1	{5}	.077625	.000043*	.200272	.000025*	.007465*	.000178*
2	3	2	{6}	.000068*	.669433	.000043*	.392378	.000018*	.082987
4	1	1	{7}	.097133	.526580	.001613*	1.000000	.000036*	.828520
4	1	2	{8}	.000043*	.429095	.000016*	.026717*	.000022*	.001393*
4	2	1	{9}	.669433	.000068*	.669423	.026717*	.000027*	.203003
4	2	2	{10}	.000043*	.828520	.000015*	.236097	.000020*	.031265*
4	3	1	{11}	.106879	.000046*	.406029	.000029*	.003909*	.000210*
4	3	2	{12}	.001847*	.669433	.000039*	.795704	.000015*	.392378
6	1	1	{13}	.795704	.026717*	.203003	.429095	.000020*	.669423
6	1	2	{14}	.001613*	.904430	.000036*	.703111	.000046*	.332104
6	2	1	{15}	.797794	.003955*	.389002	.267482	.000012*	.668006
6	2	2	{16}	.006817*	.913523	.000054*	.669423	.000039*	.429095
6	3	1	{17}	.000010*	.000018*	.000057*	.000036*	.830980	.000029*
6	3	2	{18}	.610842	.082987	.082987	.575202	.000023*	.669433
8	1	1	{19}	.787457	.000930*	.529502	.141029	.000010*	.503790
8	1	2	{20}	.000042*	.738757	.000046*	.257309	.000019*	.038458*
8	2	1	{21}	.804081	.000048*	.514645	.015645*	.000024*	.148935
8	2	2	{22}	.346856	.239037	.018343*	.486077	.000029*	.875029
8	3	1	{23}	.000193*	.000015*	.008351*	.000029*	.188685	.000023*
8	3	2	{24}	.781217	.011137*	.282146	.386240	.000015*	.756675
10	1	1	{25}		.000316*	.575202	.082987	.000032*	.392378
10	1	2	{26}	.000316*		.000039*	.610842	.000016*	.203003
10	2	1	{27}	.575202	.000039*		.001393*	.000087*	.026717*
10	2	2	{28}	.082987	.610842	.001393*		.000033*	.669423
10	3	1	{29}	.000032*	.000016*	.000087*	.000033*		.000026*
10	3	2	{30}	.392378	.203003	.026717*	.669423	.000026*	