READING FLUENCY IN CHILDREN OF EARLY PRIMARY-SCHOOL-AGE: ASSESSMENT AND TARGETED INSTRUCTION.

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CONTENTS

CONTENTS .... **II**

THESIS SUMMARY .... **III**

CERTIFICATION .... **V**

ACKNOWLEDGEMENTS .... **VI**

CHAPTER ONE **8**

INTRODUCTION 8

CHAPTER TWO **61**

UNDER WHAT CONDITIONS IS RAN RELATED TO READING … OR NOT? 61

CHAPTER THREE **109**

ENHANCING CLASSROOM ASSESSMENT PRACTICES: 109

CHAPTER FOUR **151**

REPEATED READING OF WORDS AND PASSAGES IMPROVES FLUENCY BUT NOT RAN 151

CHAPTER FIVE **201**

DISCUSSION 201

THESIS SUMMARY

Investigation of RAN (the ability to name quickly and accurately a set of visually presented, highly familiar symbols, such as colours, objects, digits or letters) has resulted in its emergence as an important predictor of children's reading abilities independent of letter-knowledge and phonological awareness (PA). The literature indicates that assessment including both PA and RAN allows for subtyping of beginning readers, in a manner which could assist education practitioners to design targeted instruction. Despite the established correlation of RAN with reading, this measure is underutilised in primary classrooms in Australia as an important indicator of reading development, and the basis of its association with reading continues to be debated. One aim of this research was to shed further light on the nature of the RAN-reading association through an examination of: (1) RAN's ability to predict reading independently of PA and letter-knowledge; and (2) the way in which the RAN-reading association varies according to the reading measures used and the nature of the RAN task in regard to the stimuli to be named and the direction of scanning.

A third aim was to investigate a promising approach for enhancing reading fluency in early readers; namely, Repeated Reading (RR). A growing body of research suggests that RR might improve automaticity in reading and as a result text reading comprehension; but further evidence is required regarding the way in which RR might work. One possibility is that RR improves fluency by improving RAN. If so, both processes should respond to RR intervention, a third issue that was investigated in this thesis.

The study was conducted in two phases. In Phase 1, 74 Australian children from grades 2-4 completed a range of standardised and non-standardised assessments to measure variables associated with successful early reading. Subgroups of children with selective deficits in PA or RAN were identified and compared in terms of reading performance; and the diagnostic value of various forms of the RAN task as an early indicator of reading difficulties was examined. Phase 2 of the study sought to compare the effectiveness of two types of RR treatment (single-words vs. passages of connected text), for a subgroup of 13 children who had average or below-average reading fluency despite word decoding skills within the typical range. A "no-treatment” control group comprised 7 additional participants.

The findings of the research emphasize the importance of ensuring that the assessment battery we use to diagnose reading difficulties in our early primary-school-aged students incorporates all aspects of reading, including fluency. Whilst our findings indicate that implementing RR using single-words and passages does not lead to an improvement in RAN, gains in passage reading fluency makes this a worthwhile intervention for further investigation.

CERTIFICATION

This work has not previously been submitted for a degree or diploma in any university. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

The research presented in this thesis was approved by the Macquarie University Research Ethics Committee (Reference Nos. 5201300176; 5201500416).

(Signed) Date: 24th October, 2017

Joanne Elizabeth Fitzgibbon

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CHAPTER ONE

INTRODUCTION

A series of studies is presented reporting on an investigation of reading fluency development in early primary-school-aged children. The need to closely monitor children's reading development is well-established in the literature in order to: (1) highlight in a timely fashion children who experience reading difficulties; (2) determine exactly which areas of the reading process cause difficulties for children; (3) inform decision making about any necessary adjustments to teaching; and (4) implement timely and targeted instruction strategies as required (Catts, 2017; Kuhn, Schwanenflugel & Meisinger, 2010; Meisinger, Bloom & Hynd, 2010; Moats, 1999; Nation & Snowling, 1997; Torgesen, 1998). Because failure to administer appropriate measures to assess reading and related skills could result in misdiagnosis and/or mistreatment of developing readers, knowledge of which aspects of reading to assess and which measures will provide the most useful information is essential for classroom teachers and practitioners alike (Meisinger et al., 2010). The studies that are reported in the three papers that follow were designed, first, to investigate the utility of the rapid automatised naming task (RAN; the ability to name quickly and accurately a set of visually presented, highly familiar symbols, such as colours, objects, digits or letters) to identify students for further detailed assessment and targeted reading instruction; and second, to investigate the efficacy of Repeated Reading (RR) intervention (using single-words and passages) in children with average or below reading fluency.

Since the focus of this investigation is children's reading fluency development, the thesis begins with a brief review of literature reflecting what we currently know about the importance of teaching children to read fluently; what skills are necessary to learn to read; what fluent reading looks like; and the importance of thorough assessment of all aspects of reading. Next, a brief history of RAN is provided including a description of literature surrounding its importance as a predictor of children's reading abilities. The review finishes with a summary of work surrounding Repeated Reading (RR), a promising approach for remediation of deficits in reading fluency.

Teaching children to read

The importance of learning to reading fluently

Reading is an essential skill for academic learning, both school-based and beyond; later employment opportunities; and confident participation in society. Evidence of a relationship between difficulties in learning to read and subsequent behavioural and psychological issues is well-established in the literature. These issues include inability to participate fully in classroom learning activities, self-esteem problems, and anti-social behaviours exhibited both in the classroom and the wider community (Bullis & Walker, 1994; Morgan, Farkas, Tufis & Sperling, 2008; Smart et al., 2017).

During the primary school years, our goal as teachers is to create skilled, confident, independent readers who are able and willing to participate in reading for learning and for pleasure (Schwanenflugel et al., 2006). Importantly, a strong relationship exists between early reading difficulties, poor motivation, and reading avoidance, with some low progress readers only engaging in reading outside of the classroom about one third of the time that their skilled peers do (Morgan, Fuchs, Compton, Cordray & Fuchs, 2008; Wigfield & Guthrie, 1997). Attending to the factors that contribute to reading failure, poor motivation, and avoidance is crucial, as all lead to minimal practice of the necessary skills associated with good reading; furthermore, the amount of time engaged in reading has been shown to predict reading achievement (Cunningham & Stanovich, 1998; Guthrie, Schafer & Huang, 2001). Conversely, promoting engaged reading can alleviate many associated factors with reading difficulties (Morgan & Fuchs, 2007). Dysfluent reading is one of these contributing factors; but that said, becoming a fluent reader can prove challenging for some students, as it is not a natural process like speaking, but rather a complex set of skills that requires explicit, systematic instruction (Moats, 1999).

Skills and processes associated with learning to read

A variety of literature informs educators of factors that can influence the acquisition of proficient reading skills. Both short-term memory, the ability to hold and process linguistic information, and long- term memory, which provides for such information to be learnt and stored for later and recurrent retrieval, are important for effective reading (McDougall & Donohoe, 2002; Siegel, 1994). Processing speed, or the ability to perform simple repetitive tasks quickly (Shanahan et al., 2006), and RAN (Denckla & Rudel, 1976) are all associated with reading success. Expressive and receptive language skills (Catts, Adlof & Weismer, 2006; Nation & Snowling, 1998;) and further cognitive aspects, such as attention and non-verbal cognitive ability are likewise known contributors to reading capability (Felton & Wood, 1989). Additionally, environmental factors, such as familiarity with concepts related to books and print, and level of maternal education have been shown to relate to reading development (Stanovich & Cunningham, 1993).

Taking into consideration the many factors associated with learning to read there has been considerable investigation both nationally and internationally as to which methods are best when it comes to the assessment, teaching, and remediation of reading. In the US, the *National Reading Panel* (NRP; NICHD, 2000), in Australia, the *National Inquiry into the Teaching of Literacy* (NITL; Department of Education Science & Training, [DEST], 2005), and in the UK, the *Independent Review of the Teaching of Early Reading in the United Kingdom* (Rose, 2006) extensively reviewed the vast amount of literature available on these topics. Common amongst their recommendations was the view that for reading instruction to be most effective it must incorporate explicit instruction in phonemic awareness (the ability to consciously identify and/or manipulate individual phonemes); systematic phonics instruction (knowledge of letter-sound mappings and how sounds combine to form words); and evidenced-based methods to improve fluency and comprehension. In addition, assessment of reading must be timely, ongoing, and inclusive of all components of reading.

In association with these skills, the literature also recognizes more specific linguistic processes as vital for reading success (Melby-Lervag & Lervag, 2014; National Early Literacy Panel [NELP], 2008). In particular, knowledge of syntax (grammatical structures of sentences), semantics (word and text meanings), morphology (structure of words), and orthography (conventions for writing a language or spelling) further help children to develop the ability to read aloud with increasing speed and expression, to read silently, and to make meaning of what they have read (NICHD, 2000). These multiple cognitive and linguistic processes working together both simultaneously and accurately is described by Norton and Wolf as a *circuitry* of reading (2012, p. 430).

Simple View of Reading

While acknowledging the complexity of the reading process, Gough and Tunmer (1986) proposed that successful reading relies primarily on the development of two vital processes: decoding or word recognition (which they described as fast and accurate reading of known and unknown words in both isolation and connected text), and language comprehension, also referred to as listening comprehension (or the ability to gain meaning from spoken language). As stated by Hoover and Gough (1990), the ability to read words, but not understand what is meant by the text is not reading; both are important for reading development, and neither is sufficient on its own (see 1 below).

(1) Decoding (D) x Language Comprehension (LC) = Reading Comprehension (RC)

In a practical sense, the Simple View of Reading (Gough & Tunmer, 1986) provides classroom teachers with a clear understanding of the instruction required to support children's reading development. This model emphasises the need to ensure that children become fast and accurate decoders; and as such highlights the importance of readers' abilities to swiftly access their mental lexicon for orthographic representations of words (Hoover & Gough, 1990). The teaching of word recognition skills is therefore crucial, through explicit instruction in both phonological awareness (PA; the ability to reflect on and manipulate the sound structure of language) and letter-knowledge (knowledge of how printed letters, *graphemes*, map onto spoken sounds, *phonemes*). In addition, the model supports the teaching of content knowledge throughout the curriculum and in all grades to support the development of language comprehension skills.

Although the simple view of reading provides a structure of the essential components required for reading comprehension, and recognises the importance of word recognition, it alone does not provide a detailed explanation of how skilled readers learn to read words aloud; however, such information is vital for teachers in planning targeted assessment and instruction. Though it is agreed that phonics instruction is essential for students to be able to sound words out, mere lack of phonological decoding problems does not guarantee successful reading of all words. In fact, many words in the English language are not decodable (e.g., meringue, yacht, quay), meaning they can only be pronounced by sight. It has long been recognised that oral single-word reading ability is positively associated with reading comprehension skill (Perfetti & Hogaboam, 1976); and it is therefore crucial that educators have a clear understanding of which particular aspects of oral word reading are causing difficulty for students, so as to provide the necessary *targeted* instruction. With this need in mind, the Dual-Route Model of single-word oral reading (DRM; Coltheart, Rastle, Perry, Langdon & Ziegler, 2001) provides essential additional information for practitioners, beyond that provided by the Simple View.

Dual-Route Model of Reading (DRM)

English is described as an alphabetic language because the letters (graphemes) in printed words represent the sounds (phonemes) in spoken words. However, within this description are two subsets: deep and shallow orthographies. English is regarded as a deep orthography because its phonology is inconsistent; that is, not all English words follow the accepted grapheme-to-phoneme correspondence (GPC) rules. Such words are described as exception (or irregular) words, because their pronunciations cannot be derived through the application of rules. In contrast, both regular words (e.g., candy, boat, fleet) and nonwords can be pronounced correctly using the accepted GPC rules.

According to the DRM the ability to read both exception words and nonwords reflects the operation of two cognitive processing mechanisms for converting print to speech: a non-lexical, phonological decoding process, which involves the application of GPC rules (GPC route); and a more efficient lexical process, which involves recognising a word's orthography and retrieving its associated phonological representation directly from memory (lexical route). It is proposed that proficient readers use these routes simultaneously; and that struggling to acquire either of these mechanisms can result in reading difficulties (e.g., Castles & Coltheart, 1993).

According to this model, once a printed word appears the reader uses its visual features to identify constituent letters. Words are then processed simultaneously by both routes. Importantly though, exception words will only be read *correctly* via the lexical route (because the GPC route will pronounce the word as though it were regular). For nonwords on the other hand, there will be no lexical entry (orthographic representation), so only the GPC route will provide the correct pronunciation. In this system the more direct, lexical route operates quickly (as it searches for a match in parallel), whereas the GPC route takes longer, because it applies letter-sound rules serially, letter by letter, from left-to-right.

Early findings established a strong correlation between difficulties in acquiring PA and subsequent difficulties in acquiring efficient reading skills (Bradley & Bryant, 1978; Wagner & Torgesen, 1987). Substantiated by those early findings, evidence has continued to support the importance of explicit, systematic training and assessment of letter-knowledge and PA, in order to assist early readers in the process of decoding single-words and later reading passages of text (Duff & Clarke, 2011; Ehri, Nunes, Stahl & Willows, 2001; Muter, Hulme, Snowling & Stevenson, 2004; Vellutino, Fletcher, Snowling & Scanlon, 2004). Nevertheless, PA, letter-knowledge, and nonword reading remain common sources of difficulty in the primary classroom. If standardised measures demonstrate that children have difficulties in these areas, targeted phonics instruction should be effective.

On the other hand, some students can be accurate readers of nonwords but have difficulties in reading exception words. Problems with letter-knowledge or PA would not be expected for readers who demonstrate this type of selective reading difficulty, making phonics instruction inappropriate. Correct identification of students who have trouble reading exception words is essential, and well-planned targeted instruction should promote the establishment of words' orthographic representations (letter-patterns) in the lexicon; for example, through improving the efficient recognition of these common patterns in words (e.g., Law & Cupples, 2017).

Relevant to this investigation, and as previously stated, the ability to accurately read aloud all written words, sentences, and passages is essential for successful reading development, but it is not sufficient. Although the DRM is useful for understanding selective difficulties in oral reading *accuracy*, another aspect of skilled reading is *fluency*.

Fluent reading – what does it look like?

Fluent reading is reflected not only in accurate word reading but also satisfactory speed. Since readers can be accurate single-word decoders but still not read fluently (Meyer & Felton, 1999), fluency is another aspect of reading ability that needs to be assessed to ensure informed decisions are made regarding targeted instruction and effective intervention.

The National Reading Panel identified fluency as the reading skill "most neglected" in teaching (see Allington, 1983). However, poor fluency is a reliable predictor of future reading comprehension difficulties (Stanovich, 1991), and as such the importance of explicitly teaching fluency should not be under-estimated. Difficulties with fluency often emerge in children during grades 1 and 2, once basic decoding processes have been achieved. By grade 3, reading fluency deficits become more evident as students begin to read longer and more complex texts (Therrien, Kirk & Woods-Groves, 2012). Problems with reading fluency are often characterised by slow, laborious oral reading of single-words and passages of text, and can be associated with poor orthographic processing speed. It has been suggested that students with poor reading fluency are using essential cognitive resources to merely decode words, and have as a result, very little cognitive load left to help in assigning a meaning to the text, interpreting that meaning, and making connections with other ideas (Alt & Samuels, 2011; Samuels, 1994). An essential element of passage reading fluency therefore is the accurate and rapid recognition of words in text, which relies on orthographic knowledge (Barker, Torgesen & Wagner, 1992; Ehri, 2005; Perfetti, 1992).

Alongside the comprehension difficulties associated with a lack of fluent reading, children who read too slowly can take longer to complete in-class and homework assignments than more skilled students and might not even complete work (Moats 2001; Pikulski & Chard, 2005; Rasinski, 2000), all of which contributes to low literacy and poor academic attainment. It is therefore of utmost importance that educators know what it means to be a fluent reader, as their conceptions will ultimately influence decision-making in the planning of quality instruction and effective intervention.

Various definitions of reading fluency have been offered in the literature to date. Armbruster, Lehr and Osborn (2001) defined fluency as the ability to decode rapidly and accurately. Hudson, Lane and Pullen (2005) described it as the ability to recognise words automatically and read with accurate phrasing. In so doing, an additional element (i.e., expressiveness/prosody) was added to the definition, regarded by some as critical for fluency (Kuhn et al., 2010; Kuhn & Stahl, 2003; Torgesen & Hudson, 2006). Others, however, claim that the inclusion of prosody in a definition of fluency is irrelevant, because prosody is a by-product of accurate and fast word and text reading that enables expressive reading to emerge (Miller & Schwanenflugel, 2006).

Although contention surrounds the definition of reading fluency, it is generally accepted that accuracy of word recognition, speed, and reading orally with expression are all *indicators* of fluency. Thus, Meyer and Felton stated that fluent reading is "the ability to read connected text rapidly, smoothly, effortlessly and automatically with little conscious attention to the mechanics of reading such as decoding" (1999, p. 284). Some investigators would however, question the adequacy of a definition that disregards the ultimate goal of reading, namely, the ability to use the information provided in the text for the purpose of comprehension (Norton & Wolf, 2012; Samuels, 2007; Wolf & Katzir-Cohen, 2001). In accordance with this view, Norton and Wolf suggested that for a complete definition of fluency we must return to the earlier work of Wolf and Katzir-Cohen wherein the term "fluent comprehension" was originally developed as follows:

> *…a manner of reading in which all sublexical units, words, and connected text and all the perceptual, linguistic, and cognitive processes involved in each level are*

processed accurately and automatically so that sufficient time and resources can be allocated to comprehension and deeper thought (Wolf & Katzir-Cohen, 2001 in Norton & Wolf, 2012, p. 429).

Other investigators also see a definition of fluency that does not include the ability to simultaneously decode and comprehend as insufficient for describing what it 'looks like' to be a fluent reader (Alt & Samuels, 2011; LaBerge & Samuels, 1974; Samuels, 1994, 2007). According to these researchers, it is the simultaneous functioning (automaticity) of all relevant components (accuracy, speed, expression and comprehension), that identifies readers as being fluent. In fact, as early as the mid-1980s Perfetti's 'verbal efficiency theory' identified the need for low order reading skills such as accuracy to reach minimum effort so that higher order skills, such as comprehension could be attained simultaneously (Perfetti, 1985).

To conclude this section, common amongst the various definitions of fluency is a general consensus that assessment should encompass aspects of oral reading rate and accuracy to allow for efficient comprehension of text. In this regard, a final definition is offered from Pikulski and Chard (2005): "Reading fluency refers to efficient, effective word recognition skills that permit a reader to construct the meaning of text. Fluency is manifested in accurate, rapid, expressive oral reading and is applied during, and makes possible, silent reading comprehension" (p. 510).

The importance of effective assessment practice

Information and opinions regarding the nature of reading fluency are of clear benefit to teachers in providing knowledge of which aspects of reading need to be assessed in order to monitor students for any difficulties in acquiring fluency. Essential to providing effective classroom instruction, any necessary adjustments to teaching, and specific intervention is the knowledge of which measures to use in monitoring children's reading development and reading-related skills (Kuhn et al., 2010; Moats, 1999; Torgesen, 1998).

While recognising the important contributions that letter-knowledge (Melby-Lervag, Lyster & Hulme, 2012) and PA make in children's early reading development, there is equally important evidence for the benefits of including a RAN task in a battery of reading assessments, because performance in RAN is also a strong predictor of reading ability, especially fluency (Georgiou, Parrila, Manolitsis & Kirby, 2011; Lervag & Hulme, 2009; Norton & Wolf, 2012). Over the last 40 years investigation into RAN has resulted in its emergence as an important predictor of children's reading abilities, independent of both letter-knowledge and PA (Bowers, 1993; Denckla & Rudel, 1976; Georgiou et al., 2011; Norton & Wolf, 2012).

Despite its potential use as an indicator of reading fluency, the RAN task is not commonly used in Australian classrooms. One aim of the current investigation was to provide further evidence, within an Australian context, that inclusion of RAN in a battery of reading assessments used to monitor reading development and related skills, would assist teachers and other practitioners to identify children who have (or might develop) passage-reading difficulties regardless of having already mastered the processes underpinning *accuracy* in single-word decoding.

The literature indicates that assessment inclusive of both PA and RAN allows for subtyping of poor readers, which could assist education practitioners in the design of targeted instruction. As proposed by Wolf and Bowers (1999), and later extended by other studies (e.g., Compton DeFries & Olson, 2001; Meisinger et al., 2010; Ozernov-Palchik et al., 2016) the "double deficit" hypothesis (DDH) proposes that PA and RAN are independent predictors of reading ability. According to this view, early readers can have singular deficits in either

PA, or RAN, or a double deficit in both, with the latter children being identified as the most impaired of all in terms of reading fluency (Wolf & Bowers).

The DDH raises two important points for consideration. First, as mentioned previously, the knowledge of which measures to use to monitor children's reading and/or pre-reading development is vital; for example, if measures of only PA and letter-knowledge are used for assessment purposes, students with a singular deficit in RAN would remain undetected because their PA skills are complete. Second, the ability to subtype readers into particular deficit categories provides important information for the planning of targeted instruction. Those with a single deficit in PA should benefit from explicit, systematic training in the ability to hear, identify, and manipulate individual sounds in spoken words and the alphabetic principle, that is, knowledge of how printed letters (graphemes) represent sounds (phonemes) which form words (Cupples, 2001; Duff & Clarke, 2011; Fielding-Barnsley, 1997; Vellutino et al., 2004; Wagner et al., 1997). However, students with single RAN deficits would not be expected to benefit from such phonics-based instruction (Norton & Wolf, 2012; Wolf, Bowers & Biddle, 2000), but rather treatment that supported improvements in fluency, such as Repeated Reading (RR; Kuhn & Stahl, 2003; Therrien, 2004).

A focus on RAN

The history

The RAN task (Denckla & Rudel, 1976) originated from early work by Geschwind and Fusillo (1966) who observed that difficulties in colour naming by patients with reading impairments, resulted from loss of visual-auditory connections in certain pathways of the brain, particularly the angular gyrus (the region of the brain most associated with language and cognition). Geschwind and Fusillo proposed that the same neural processes that support rapid naming of colours might also be closely associated with the automaticity required for proficient reading. On this view, the language domain of the brain (concerned with expressive and receptive language, grammar, sentence structure, and word meanings) and the executive domain (controlling processing speed, working memory, planning, and organisation) both contribute to the skills necessary for automaticity of stimuli retrieval. Such automaticity, in for example, the retrieval of words, is a vital aspect for fluent reading.

The subsequent research of Denckla and Rudel (1974, 1976) extended the work of Geschwind and Fusillo (1966) and led to formulation of the traditional RAN task used today. Stimuli were presented in the same configuration used by Geschwind and Fusillo, with 50 coloured squares, representing 5 different colours, ordered in 5 rows of 10 each, with the various colours recurring in random order. Future versions of the RAN test were developed to include objects, digits and letters as well as colours (Denckla & Rudel, 1976). During this same period, other researchers began to discover that students with general learning difficulties and more particularly, those with developmental reading deficits, also displayed poor performance on RAN tasks. In this vein, investigations by LaBerge and Samuels' (1974) focused on the importance for all linguistic and cognitive processes to work together to the point of *automaticity* in order to enable fluent reading. Their ideas led to interest in measuring RAN because of its correlation with fluent reading performance. An abundance of studies followed within the realms of international research literature, as regards the nature of RAN. One aim of the current investigation was to address a gap within the literature at a national level, and in so doing advocate for the inclusion of the RAN task in assessment practice within Australian classrooms, to assist in identifying at an early stage of development children at potential risk of later reading fluency difficulties (see Papers 1 and 2).

The current research was conducted in the knowledge that previous studies have contributed extensive evidence in support of the view that RAN performance has the potential to predict current and future reading outcomes in early readers, including those already identified as experiencing difficulty, even after controlling for letter-sound knowledge and PA (e.g., Bowers, 1993; Kirby, Parrila & Pfeiffer, 2003; Papadopoulos, Georgiou & Kendeou, 2009), and across a range of ages and orthographies (Georgiou, Parrila & Liao, 2008). This RAN-reading link is possibly a result of both tasks sharing the same processes necessary for success; in particular, accurate and rapid recognition, retrieval, and naming of a set of visually presented stimuli. As mentioned previously, the necessity for speed and automaticity to be assessed, alongside word accuracy and comprehension as essential components of reading fluency, adds to the value of including the RAN task within a battery of reading assessments (Norton & Wolf, 2012). There is persuasive evidence also that the RAN task is easy for teachers to administer, takes a short time to complete, and provides opportunities to identify early on children who are at risk (Georgiou et al., 2011). Inclusion of RAN is also warranted on the more general grounds that the need for timely, research-based assessment procedures to inform planning of effective classroom instruction of reading is well-documented (e.g., Foorman & Moats, 2004; Kuhn et al., 2010; National Reading Panel, 2000).

How is RAN related to reading?

RAN has been identified as a strong predictor of single-word reading abilities in primary-aged students, independent of both letter-knowledge and PA (e.g., Hulme & Snowling, 2013). RAN is also positively associated with orthographic processing skill, which is reflected most clearly in exception word reading accuracy and orthographic choice tasks (Clarke, Hulme & Snowling, 2005; Conrad & Levy, 2007; Manis, Doi & Bhadha 2000). Some evidence also shows that RAN is more strongly linked with timed than untimed word reading tasks (Abu-Hamour, Urso & Mather, 2012). In terms of RAN's link to passage reading, the association seems to be stronger for measures of oral reading fluency, in terms of rate (Lervag & Hulme, 2009; Savage & Frederickson, 2005), than for comprehension; and with oral rather than silent reading (Georgiou, Parrila, Cui & Papadopoulos, 2013; Papadopoulos, Spanoudis & Georgiou, 2016).

Several theoretical, accounts as to how RAN is related to reading have been proposed. First, the RAN-reading link has been explained in terms of both skills requiring efficient and rapid access to stored phonological representations in long-term memory (Torgesen, Wagner, Rashotte, Burgess & Hecht, 1997; Wagner & Torgesen, 1987). Whilst a popular theory, stronger evidence suggests that RAN accounts for unique variance in reading development, independently of PA and letter-knowledge (Denckla & Rudel, 1976; Hulme & Snowling, 2005; Kirby et al., 2003; Schnatscheider, Fletcher, Francis, Carlson & Foorman, 2004; Wolf et al., 2000). This view accords with the "double-deficit" theory (DDH; Wolf & Bowers 1999), which proposes that readers can have singular deficits in either PA or RAN, or a double deficit in both.

A third view proposed initially by Bowers, Golden, Kennedy and Young, (1994) is that the RAN-reading relationship is due to RAN's association with orthographic processing. This alternative account of RAN as a unique predictor of orthographic processing has been supported by others in the literature (Bowers & Wolf, 1993; Clarke et al., 2005; Manis et al., 2000). As explained by Bowers et al. if children are slow at identifying letters printed in words, they may fail in activating those letters automatically in memory, thereby creating difficulties in establishing orthographic representations of words. Such difficulty would subsequently result in difficulties with single-word and passage reading fluency, as both are reliant on accurate, rapid recognition of words in text. Badian (1997) in fact proposed expanding the DDH to a triple deficit hypothesis, suggesting that readers can also have a single deficit in orthographic knowledge.

Finally, the RAN-reading link may be underpinned by a common association with processing speed; that is, because both rapid naming and fluent reading require efficient performance. While some evidence supports this view (e.g., Kail & Hall, 1994), it is the less favoured of the theoretical accounts.

To further explore the processes involved in rapid naming and the diagnostic value of various forms of the RAN task, researchers have looked at particular components of this measure in the hope that such investigations will provide clearer answers as to how RAN is actually related to reading. Components include: (1) the stimulus types presented in the RAN task (colours, objects, letters & digits); (2) the serial nature of the task; (3) the time it takes students to articulate the presented items; and (4) the pause time taken between articulation of each presented stimulus.

Components of RAN

Stimulus types used in RAN tasks: digits, letters, objects and colours

One predominant question in relation to the RAN task is whether it is related to reading because of its dependence on the rapid automatised naming of any stimulus items, or due to its dependence on rapidly accessing highly familiar (sometimes called overlearned) stimuli such as, letters and digits. If it is the act of rapidly naming that is of greater importance, we would expect to find the results from *all RAN tasks* being related similarly to reading measures.

RAN measured prior to school predicts later reading performance.

Research suggests that including a measure of non-alphanumeric RAN in a screening battery prior to formal school entry could increase the likelihood of detecting early children who might be at risk of future reading difficulties, and in addition, enable swift delivery of targeted instruction (Caravolas et al., 2012; Georgiou et al., 2011; Lervag & Hulme, 2009; Ozernov-Palchik et al., 2016; Puolakanaho et al., 2007). If so, assessment of RAN (colours and objects) even before letters are learnt and instruction in reading has begun, could provide important information for teachers to use in planning effective instruction.

Bishop (2003) followed 103 kindergarten students over a 2-year period and found that a combination of letter-knowledge, PA, and RAN assessed in the first year of schooling was the best predictor of early reading performance. Similarly, Puolakanaho et al. (2007) tracked children at ages 3.5, 4.5 and 5.5 years and showed that measures of letter-knowledge, PA and RAN (objects), strongly predicted a child's risk for reading difficulties. On the basis of these results they advocated for assessment of children as young as 3.5 using these measures in order to provide important information to guide the planning of targeted instruction.

Following on from these studies, Cronin (2013) identified the importance of including assessments of PA and RAN in children's preschool years to identify those at potential risk of later reading difficulties. Within this study 84 children were followed from preschool to grade 5. Conclusions from measures of single-word reading, nonword reading and comprehension of written texts, suggested that measures of PA and RAN taken in the early years of schooling are of more diagnostic value than those taken later in schooling; in particular RAN objects scores attained during preschool and kindergarten predicted reading at every age level.

The important, independent contributions of letter-knowledge, PA and RAN to predicting future reading ability was also confirmed by Schatschneider et al. (2004) in their longitudinal study of a kindergarten sample and their subsequent reading outcomes in grades 1 and 2. Evidence from this study suggests that measures of visual perception, receptive and expressive vocabulary, and syntax were less predictive of future reading outcomes than measures of letter-knowledge, PA and RAN (objects and letters).

Likewise, Ozernov-Palchik et al. (2016) in a two-year study of 1,215 preschool and kinder children using measures of letter-knowledge, PA, RAN (objects and colours) and verbal memory, highlighted the possibility of early identification of children at risk of reading difficulties. The data collected from these measures enabled the children to be assigned to six specific sub-types, based on performance in pre-school and kinder, which predicted later reading ability at end of grade 1: average performers (who were consistently average in letter-knowledge, PA, and RAN), low average performers (who were consistently below average), high performers (who were consistently above average), PA risk, RAN risk and double-deficit risk. Their study in particular has important implications for accurately identifying, as early as possible, children at risk of reading difficulties and following up with targeted instruction in order to prevent and/or remediate later problems, including reading fluency.

Similar findings were reported by Georgiou et al. (2011) in a study of 97 English-speaking and 70 Greek-speaking children who were followed from kinder to grade 3. Non-alphanumeric RAN was a significant predictor of reading abilities for English-speaking students in grade 1, and for Greek-speaking students in kinder and grade 1. Along similar lines, Lervag & Hulme (2009) reported a 3-year longitudinal study, in which they found that, for children in the year prior to formal reading instruction, non-alphanumeric RAN was a strong predictor of later abilities in text-reading fluency, independent of both PA and letter-knowledge. Finally, Wolf, Bally & Morris (1986) in a study of 83 children who were followed from kindergarten to grade 2 found that measures of RAN (colours, letters and numbers), predicted all types of reading (silent reading and comprehension; oral passage reading; and single-word accuracy) in subsequent grades.

The studies reviewed above are especially important in terms of the insight they bring to the discussion of RAN as an early predictor of current and future reading outcomes. In particular, the evidence suggests that measuring RAN in pre-readers and/or early readers could provide important information regarding selective reading deficits downstream. The importance of this conclusion for classroom practice is two-fold. It suggests that: (1) reading assessments must include measures that reflect the reading process (letter-knowledge, PA *and* RAN); and (2) assessment must take place in a timely fashion to allow for early identification of those children who might be at risk of reading difficulties to enable the proactive delivery of targeted instruction.

RAN measured during primary school diagnostic of reading performance.

As noted above, evidence suggests that non-alphanumeric RAN could be an important predictor of later reading abilities when assessed in younger children before they begin to learn to read. Beyond kindergarten, however, and especially once children begin reading instruction, there is overwhelming evidence that the influence shifts to alphanumeric RAN (e.g., Cardoso-Martins & Pennington, 2004; Clarke et al., 2005; Lervag & Hulme, 2009; Misra, Katzir, Wolf & Poldrack, 2004; Savage & Frederickson, 2005; Schatschneider, Carlson, Francis, Foorman & Fletcher, 2002; Schatschneider et al., 2004; Wolf et al., 1986; Wolf & Bowers, 1999). Thus, once children are more regularly exposed to letters and digits, it is alphanumeric RAN that becomes more strongly related to reading performance (Norton & Wolf, 2012; Wolf et al., 1986). More specific to this investigation, is the notion that the RAN task is an important measure for its effective diagnostic value of reading difficulties in children no longer *learning to read* but expected to be *reading to learn*.

The importance of automatic letter identification in reading has been discussed previously in relation to the work of Laberge and Samuels (1974). With respect to the RAN-reading link, the argument is that items to be named in the RAN task must also be "automatised." Digits and letters, being limited in number, receive more repeated exposure than do colours and objects, and once learnt become more automatic in their retrieval than objects or colours, which belong to categories with a higher number of possible members (Misra et al., 2004). The importance of *retrieval automaticity* was demonstrated in the previously mentioned study by Wolf et al. (1986) wherein 83 children were tracked during their first 3 years of reading acquisition. Findings showed that both alphanumeric and non-alphanumeric RAN assessed in kindergarten predicted reading in grade 2; however, as proposed by Wolf et al. (1986) alphanumeric RAN becomes a more automatised skill in comparison to non-alphanumeric RAN once letter/digit recognition becomes automatic (familiar) in grades 1 and 2. At that time, an obvious difference occurs in the rate of retrieval of alphanumeric compared to non- alphanumeric stimuli and in their relative association with reading performance; that is, alphanumeric RAN is faster and a stronger predictor of reading. These findings suggest that performance on alphanumeric RAN could assist in differentiating good readers from those who are experiencing difficulty in learning to read, whereas RAN for colours and objects might provide little information in terms of reading development, once children's familiarity of letters and digits increases (see Paper 1).

Results reported by Savage & Frederickson (2005) support the proposed association between alphanumeric RAN and reading in a group of older poor readers (approximately 10 years of age on average). They found that RAN (digits) along with PA contributed separately to various components of reading in their sample. Reading rate was predicted by RAN digits, whereas word reading accuracy and comprehension abilities were more strongly predicted by PA tasks. Similarly, Clarke et al. (2005) investigated performance on RAN (letters and digits), exception and nonword reading, and PA in a sample of 30 children, 8 – 11 years of age. The results indicated that after controlling for PA, alphanumeric RAN accounted for independent variance in exception word reading. The association between exception word reading and alphanumeric RAN was also shown in a previous study of 85, grade 1 students, wherein Manis et al. (2000) discovered that RAN (digits) accounted for unique variance in reading, once PA and vocabulary knowledge were controlled; RAN objects on the other hand accounted for minimal variance.

In contrast with the general pattern of findings in the literature, Kruk, Mayar and Funk (2014) reported an investigation of 52 at-risk readers and 69 not-at-risk readers who were tracked from grade 1 through to grade 3. Kruk et al. found that RAN (objects and colours) measured in grade 1 accounted for unique variance in exception word reading in grade 2. More recently, Papadopoulos et al. (2016) found that either version of the RAN task (alphanumeric or non-alphanumeric) predicted oral, but not silent, reading fluency in 286 Greek students in grades 1 and 2. Papadopoulos et al. concluded that RAN was more closely related to oral reading because both require articulation; further evidence regarding the association between RAN and silent reading was sought in the current investigation (see Paper 2).

The importance of investigating which specific RAN measures (alphanumeric or non-alphanumeric) most efficiently predict reading abilities (such as accuracy, rate, and comprehension) at which point in time in reading development lies partly in its relevance for helping practitioners to select the most appropriate assessment measures. In this regard, some research indicates that either version of the RAN task predicts reading development, but these studies generally examined reading in younger participants (e.g., grades 1 and 2) who are less likely to have developed automaticity in letter and digit recognition. As previously discussed, however, alphanumeric RAN is likely to be more strongly associated with reading once children's recognition of letters and digits becomes automatic. Consistent with this reasoning, evidence that alphanumeric RAN provides more diagnostic value over the longer term in reader's development remains overwhelming.

Direction of RAN task

Another aspect of the RAN task that has been investigated in regard to explaining its association with reading is its serial nature, particularly the importance of participants naming stimuli from left-to right, and top-to-bottom (Bowers & Swanson, 1991; Georgiou et al., 2013; Logan, Schnatschneider & Wagner, 2011). If the link between RAN and reading lies in the learned, directional processing of words in text, which mimics the left-to-right scanning required in the traditional RAN task (Protopapas, Altani & Georgiou, 2013), then it would be reasonable to suggest that a weaker correlation would be evident if the RAN task were presented in a different format, a possibility investigated in Paper 1.

Some studies have addressed this issue by administering the RAN task in a single-item, discrete form (e.g., de Jong, 2011; Zoccolotti et al., 2013). Comparison between discrete naming (i.e., the average naming latency for RAN stimuli presented individually via computer) or serial naming (i.e., the total time taken to name all items presented in a single multi-item array) has been undertaken to see which measure correlates more strongly with reading. Advocates of the discrete format suggest that the processes of scanning and sequencing in the serial RAN task can be prejudicial against poor readers; and that their removal ensures a truer picture of a reader' rapid naming performance (e.g., Jones, Ashby & Branigan, 2013; Jones, Branigan & Kelly, 2009). On the other hand, proponents of the serial format argue that these components mimic those of passage reading and are thus necessary aspects of the RAN task itself (e.g., Norton & Wolf, 20102).

In accordance with the latter view Norton and Wolf (2012) explained that both rapid naming and reading are dependent on many of the same individual processes becoming automatic (e.g., eye saccades, working memory, linking of orthographic symbols to phonological representations, etc.). They noted that these shared linguistic, perceptual and visual processes underpin the finding that RAN consistently predicts later reading. Furthermore, in order for any future versions of the RAN task to remain strongly correlated with reading, the original components such as serial, left-to-right processing, and a high degree of familiarity with stimulus items must be maintained. Supporting evidence for this claim comes from Wolf and Bowers (1999), who noted that correlations with reading measures were stronger for serial RAN than for discrete naming trials. Such findings suggest that the RAN-reading link may be due to the speed imposed by the continuous format, possibly replicating the automaticity required in the fluent reading of connected text.

Further evidence suggesting a difference between serial and discrete naming tasks comes from Zoccolotti et al. (2013) who compared the performance of dyslexic and non-dyslexic Italian students on serial and discrete RAN tasks for colours and digits. They found that typically developing readers performed better than below average readers on both serial and discrete tasks; whereas below average readers performed better on discrete trials regardless of the stimuli. As a result of these findings the authors suggested that the multiple subcomponents required in the serial RAN task imitate such processes in reading (i.e., processing of visual stimuli, scanning, articulation), and therefore may explain why dyslexic students are slower in RAN tasks because of the difficulty in incorporating the many individual processes required. This assertion is in line with other research suggesting that serial and discrete RAN tasks might be differentially associated with reading because of the increased emphasis on oculomotor control in both serial RAN and the reading of connected text (e.g., Kuperman, Van Dyke & Henry, 2016).

An additional question regarding the serial nature of the RAN task is whether its association with reading depends not only on the need for serial scanning but also on the *direction* of scanning required (e.g., left-to-right vs. right-to-left). In a study involving 107 grade 6 students, Protopapas et al. (2013) proposed that if RAN and reading were associated due to both requiring left-to-right and top-to-bottom scanning, then RAN-backwards would show a weaker association with reading. Measures of word reading and passage reading fluency were included in the study along with measures of RAN (digits and objects), which were presented in standard serial format (left-to-right) and in a backward direction (i.e., participants were asked to begin naming at the bottom right corner and working from right-to-left and bottom-to-top). The results, although not significant, showed correlations between RAN-backwards and reading that were stronger than those between reading and the traditional RAN task. Furthermore, Protopapas et al.'s findings were not reliant on the use of similar formatting in the reading and RAN tasks; that is, the association between RAN and reading was also evident for a measure of word-reading fluency presented in a column format (i.e., requiring top-to-bottom reading) and RAN measures presented backwards. Such findings suggest that the common need for left-to-right visual scanning cannot fully explain the RAN-reading link.

To the author's knowledge no previous investigation has compared a traditional serial RAN task (involving horizontal, left-to-right row-by-row scanning of named stimuli) with a non-traditional serial RAN task (involving vertical, top-to-bottom, column-by-column scanning). Such a comparison was conducted as part of this investigation, and the associations between each RAN task and various measures of reading were examined (see Paper 1).

Measurements of articulation and pause time

Various other aspects of RAN have been investigated in efforts to understand its association with reading at the level of particular shared mechanisms. One example is research that measured participant output in more precise increments than just total naming time; in particular, pause and articulation times (Clarke et al., 2005; Lervag & Hulme, 2009; Georgiou, Parrila & Kirby, 2006; 2009; Georgiou, Parilla, Kirby & Stephenson, 2008; Georgiou, Papadopoulos & Kaizer, 2014; Li et al., 2009; Neuhaus, Foorman, Francis & Carlson, 2001).

In the traditional RAN task participants articulate the names of visually presented stimuli (colours, objects, letters and digits), but total "naming time" necessarily includes the intermittent intervals (pauses) between each utterance. Neuhaus et al. (2001) proposed that measuring total naming time in this way does not provide the precision necessary to determine how RAN is related to reading and what specific skills within the RAN task act as a predictor of students' reading capabilities. Their reasoning would seem plausible given that both fluent reading and RAN performance closely mimic one another in terms of their requirements. In particular, both tasks require rapid shifting of attention (from one visual stimulus to the next), and rapid access to and retrieval of phonological codes from long term memory (exhibited by *pause* time); and *articulation* of phonological outputs.

Although there is some disparity in the available research as to how robust measurements of pausing and articulation time are with respect to prediction of students' reading abilities, observed differences may be explained by the range of grades being investigated. Georgiou et al. (2006) investigated 62 randomly selected English-speaking students using measures of RAN and reading (word and nonword accuracy; word and passage fluency) at the beginning of kindergarten and the end of grade 1. Pause time was found to be highly correlated with reading accuracy and reading fluency in both grades, whereas articulation time was only weakly correlated. In a related study involving older participants (60 English-speaking grade 3-5 students), Georgiou et al. (2009) found that both articulation and pause time were more strongly related to word reading fluency than to decoding. More interesting however, was the finding that pause time had the stronger correlation in younger students, but as children increased in age, so did the contribution of articulation time to reading fluency. In fact, it appeared that the unique significance of pause time to reading vastly decreased, as children became older and more experienced readers, and the contribution of articulation time increased (e.g., Georgiou et al., 2014; Georgiou, Parrila, Kirby et al., 2008;).

Finally, but importantly for classroom practice, although research examining differences between articulation and pause time provide some deeper understanding as to how these mechanisms relate to reading, Georgiou et al. (2006) also found that total RAN time and pause time both showed a similar pattern of correlations with reading outcomes. For purposes of classroom assessment, therefore, calculating RAN total time would be sufficient.

` **Contribution of RAN across varying orthographies**

Non-alphabetic orthographies.

As noted earlier, English is an alphabetic language, represented in written form using individual graphemes. Languages such as Chinese are regarded as non-alphabetic because they are constructed using characters that resemble syllables rather than individual graphemes. As such, orthographic knowledge (the ability to use the visual system to form, store, and recall words) plays a more important role than PA in the prediction of reading development in non-alphabetic languages. Nevertheless, RAN is also a significant predictor of reading abilities in non-alphabetic languages, possibly due to the visual processes necessary to learn the many characters.

Tan, Spinks, Eden, Perfetti and Siok (2005) reported a study of 131 primary-school children of mixed ability who were assessed on measures of writing, reading, PA, and RAN. The results indicated that both writing, and RAN were significant predictors of Chinese reading fluency development. Similarly, Chang et al. (2014) investigated RAN (digits) and Chinese character recognition in 1,412 kindergarten Taiwanese children from grades 1 to 3. After controlling for gender, age, socio-economic status, and non-verbal cognitive ability, students were placed into either a slow-namers group, as determined by results on the RAN task, or a matched-sample group. Measures of RAN, PA, and character recognition (where children were asked to read aloud as quickly and accurately as possible within 2 minutes) were administered over the next three years, with RAN remaining a strong predictor of character recognition in the slow-naming group for the duration of the study.

Liao et al. (2015) examined the relationship between RAN and reading fluency in Mandarin Chinese. They found that once non-verbal cognitive ability and orthographic processing were controlled, RAN performance was still related to reading accuracy and fluency. Additionally, Georgiou, Parrila and Liao (2008) reported a study of 40 Greek-speaking students, 40 English-speaking students, and 40 Chinese-speaking students, all of whom were in grade 4, and were administered measures of RAN (colours and digits) and reading (word accuracy and fluency). The results showed that RAN pause time was a stronger predictor of Chinese reading fluency than either Greek or English, and was also a stronger predictor of reading accuracy in Chinese than in Greek. On the other hand, articulation time was a stronger predictor of reading accuracy and fluency in Greek than in English or Chinese. According to Georgiou et al., these differences between languages might reflect variations in orthographic transparency. More specifically, since the relationship between letters and their sounds is relatively stable in shallow orthographies (as described below) access to the names of symbols (indicated by pause time) reaches automaticity much faster than in deep orthographies, such as English or non-alphabetic languages, such as Chinese. This interpretation also receives some support from the finding that pause time contributes less to reading in the higher grades, once decoding reaches automaticity (Georgiou et al., 2014).

Alphabetic orthographies.

Languages are described as alphabetic when the individual sounds of the language (or phonemes) map onto written symbols (or graphemes). Alphabetic orthographies differ however, according to depth: English is regarded as a deep orthography because its phonology is inconsistent; whereas languages such as German, Italian, and Greek are considered shallow orthographies because their letter-sound correspondences are generally consistent and predictable. Learning to decode is simpler in shallow orthographies, with many children becoming accurate decoders after only two years of schooling, compared to children learning to read in deep orthographies who require much longer (e.g., Caravolas, Lervag, Defior, Malkova & Hulme, 2013).

As mentioned above, there have been suggestions in the literature that the RAN-reading link might vary according orthographic depth. In a relevant study Georgiou et al. (2011) followed 97 English-speaking students and 70 Greek-speaking students from kindergarten to grade 3. They found that RAN tasks used to identify students at risk of reading difficulties are more reliable in a consistent orthography such as Greek, in comparison to English. By contrast, Moll et al. (2014) investigated five alphabetic orthographies (French, German, Hungarian, Finnish and English) to determine whether predictors for reading development were common or exclusive across orthographies. Known predictors of reading development, PA and RAN were measured in 1,062 typically developing primary-school students. Results indicated that both PA and RAN accounted for significant amounts of unique variance in reading and spelling in all five orthographies. RAN was the best predictor of reading rate, while PA accounted for higher amounts of unique variance in reading accuracy and spelling. By contrast with the findings reported by Georgiou et al. (2011), the predictive nature of RAN was larger in English than in the other four orthographies.

Findings reported by Caravolas et al. (2013) were consistent with those of Moll et al. (2014) in providing additional support for the view that, regardless of whether orthography is shallow or deep, reading development is predicted by PA, letter-knowledge and RAN. In a study involving Spanish and Czech students, Caravolas et al. found that although children may learn to read more rapidly in more predictive than in less predictive orthographies, there may be common prerequisites for learning to read in all alphabetic orthographies.

It would seem that while some differences in the RAN-reading link can be identified across languages and orthographies, there is no strong evidence on which to argue against the view that RAN is an important predictor of later reading performance (Norton & Wolf, 2012). Rather, changes in the language used for reading are not detrimental to the predictive nature of RAN.

Age as a factor in RAN's predictive ability

There is some suggestion in the literature that the reliability of the RAN task and its contribution to reading development diminish as children become older (Torgesen et al., 1997); however, de Groot, van den Bos, Minnaert & van der Meulen (2015) reported evidence to the contrary. They found that although the predictive nature of PA weakens over time, the predictive value of RAN increases. A different approach was adopted by Georgiou, Parrila, Kirby, et al. (2008), who suggested that the reliability of the RAN task and its predictive strength are strongly affected by the age of participants and the stimulus types administered. This viewpoint is supported by many studies already discussed in this chapter, which showed that different versions of the RAN task (e.g., alphanumeric vs. non-alphanumeric) contribute to reading in different ways across different stages of development. Thus, for younger children, prior to school entry and in kindergarten, RAN appears to play a predictive role in terms of measuring future reading capacity; whereas from grades 1 throughout primary school, the role of RAN is more diagnostic, in terms of providing vital, specific information in regard to children's word and passage reading deficits.

Taken together, the various findings in this area seem to indicate that RAN's contribution to reading may change with time, rather than diminish. In accord with this view, a 10-year longitudinal study of 75 Greek-speaking children reported by Georgiou et al. (2014) found that pause time was a strong contributor to the RAN-reading relationship in the early school grades, but that this impact decreased over time, with articulation time playing a more important role in later grades.

In sum, the influence of age on the RAN-reading relationship is more complex than a simple diminution in the predictive value of RAN with time. Rather, the RAN-reading relationship is determined by a complex interplay of factors including the age of participants, their language backgrounds, the particular mechanisms of the RAN task being measured, and the nature of stimuli to be named.

Treatment for fluency deficits – the case for Repeated Reading (RR)

As established previously in this review of the literature, although fluency plays a vital role in children's reading development, it is often seen to play a minor role in reading instruction programs (Allington, 1983; Buckingham, Wheldall & Beaman-Wheldall, 2013; de Lemos, 2005; Rasinski, 2000). The first step in addressing this educational gap lies in identification of children's particular reading difficulties, so that instruction can be well planned and targeted. In the context of the DDH (Wolf & Bowers, 1999, Wolf et al., 2000), students can have a single deficit in PA (associated with poor decoding), or RAN (associated with poor fluency), or a double-deficit in both; however, the focus of many intervention programmes is phonics training. While explicit, systematic teaching of phonics improves decoding (e.g., Ehri et al., 2001; Vellutino et al., 2004) it is not a surety for fluent reading (Meyer & Felton, 1999; Torgesen et al., 1997). For those children who have a singular deficit in fluency, that is their PA skills are intact, yet they read slowly and laboriously, an intervention focused on PA and letter-knowledge would not necessarily be expected to improve their reading performance. Additionally, for those with a double-deficit such a focus would only partially treat their reading difficulties. Such inaccurate or inefficient instruction only increases the number of children who seemingly do not respond to intervention. Rather than characterising these children as "treatment resisters" (Torgesen, Wagner & Rashotte, 1994), better practice would be to acknowledge that the treatment being given is inappropriate (Wolf et al., 2000).

Also established earlier in this chapter, children can be accurate single-word and passage readers, yet still not understand the meaning of the texts they read. According to some researchers, the decoding of words *with minimal effort (automaticity)* is an important component of fluent reading, which ensures the availability of sufficient cognitive resources to devote to simultaneous comprehension of larger segments of text (Alt & Samuels, 2011; Pikulski & Chard; 2005; Samuels, 1994, 2007). On the other hand, if text is read in a protracted and inefficient manner it will be difficult for the child to remember what has been read and comprehension will presumably suffer. In short, reading rate is important to allow for attention to be devoted to comprehension (LaBerge & Samuels, 1974; Rasinski, 2000).

It is encouraging to see continued research on the importance of timely student assessment, which emphasises the need to discover why students are experiencing reading difficulties and how to provide effective instruction, all of which has led to an increased focus on both targeted instruction and intervention programs (Meisinger et al., 2010; Snow, Burns, & Griffin, 1998; Wolf & Katzir-Cohen, 2001). According to the literature, RR is a promising strategy for building reading fluency in students from grade 1 and above, who are beginning to consolidate skills already taught regarding the decoding of words to accurate passage reading (Therrien & Kubina, 2006). Samuels (1979) described RR intervention as "a supplemental reading program that consists of re-reading a short and meaningful passage until a satisfactory level of fluency is reached" (p. 404). The goal should be to increase reading speed on trained and untrained text and to increase comprehension (Samuels).

Difficulties with fluent reading often emerge in children in grades 1 and 2, when reading tasks begin to demand more than basic word recognition processes. The National Reading Panel (2000) along with a growing body of research originating from the earlier work of Dahl (1974) and Samuels (1979), highlighted the effectiveness of RR as an instructional practice suitable for students with specific reading deficits in fluency, as it focuses directly on oral reading fluency by providing many exposures to the same words. The importance of providing students with such multiple exposures, is that it assists in the establishment of internal orthographic representation of the words. In particular, research suggests that RR might improve automaticity in reading and result in subsequent improvements in text comprehension (Faulkner & Levy, 1994, 1999; Kuhn & Stahl, 2003; Rasinski, 2006; Strickland, Boon & Spencer, 2013; Therrien, 2004), perhaps as a result of freeing cognitive resources for focused attention on comprehension processes (e.g., Therrien & Kubina, 2006; Meyer & Felton, 1999). In addition, re-reading of the same text in the short-term may promote improved reading performance in the longer term (Gellert, 2014).

In an effort to identify the crucial instructional components of RR, extensive reviews have reported on the history and theoretical bases of this intervention (Meyer & Felton, 1999; Therrien, 2004; Wolf & Katzir-Cohen, 2001). Whilst RR can be implemented in a variety of ways, it is commonly an approach to instruction that involves students reading and re-reading a suitable passage of text, usually at the student's instructional level; that is, between 85% and 90% accuracy (Kuhn, 2010; Rasinski, 2000). It is recommended that the text be read 3 or 4 times, preferably to an adult listener, until a previously determined fluency criterion (usually in words per minute) is reached (Therrien & Kubina, 2006). Not all researchers agree on the number of re-readings, though: Ardoin, Williams, Klubnik and McCall (2009) found that six readings produced greater maintenance effects than three. Once the desired reading rate is achieved, the student reads another passage at the same level of difficulty several times until the criterion rate is achieved again. In some instances, the child is provided with feedback on oral reading errors, as well as number of words correct, and the results are graphed (e.g., Hudson et al., 2005). When the child receives feedback on oral reading errors, it is typically provided after s/he finishes reading the passage. On these occasions, errors are discussed, and relevant sections of the passage may be read again, and/or decoding activities provided to assist with correct reading on subsequent occasions. Corrective feedback has been shown to constitute an essential component of RR intervention to enhance reading performance (O'Connor, White & Swanson, 2007; Therrien & Kubina, 2006). Specifically, it would seem plausible that those students who are the most impaired readers (i.e., those with a "double deficit") would benefit most from such feedback. Finally, with regard to efficacy, Therrien (2004) reported a meta-analysis in which he found RR to be extremely effective (effect size = 1.37) if the treatment was conducted by an adult listener, who provided corrective feedback, and students continued to re-read until an agreed criterion was reached (e.g., a target number of words read correct per minute).

Although there is considerable evidence to support the efficacy of RR for improving children's reading fluency, there is also some conjecture in the literature as to how and why RR is beneficial. In particular, does RR itself improve students' reading fluency or is the crucial factor the simple increase in amount of reading experience, regardless of the particular treatment used (Kuhn, 2004; Kuhn & Stahl, 2003; O'Connor et al., 2007). The findings summarised above regarding the effectiveness of different types of RR, seem to suggest that mere experience is not the crucial factor for students who experience fluency difficulties: Rather, it is vital to include explicit strategies to promote fluency in a reading acquisition program. Therrien et al. (2012) investigated whether the repetition of passages was an important component of reading intervention. They found significant gains in students' reading fluency in both RR and non-repetitive oral reading conditions. Equally important, however, they found that providing corrective feedback during RR treatment was a more essential component for improving reading fluency than re-reading of text.

In the context of this background literature, one aim of the current investigation was to evaluate the efficacy of different types of RR treatment in children with deficits in reading fluency; in particular, its impact on text-reading fluency and reading comprehension of connected text, as well as single-word reading fluency and RAN. Since RR would seem most appropriate for children who read slowly but with adequate levels of oral reading accuracy, these children formed the focus of a treatment study (see Paper 3). This aspect of the current research was motivated by the need for further evidence regarding the way in which RR might work. One possibility is that RR leads to an improvement in RAN (e.g., Norton & Wolf, 2012). If so, both processes should respond positively to RR treatment.

There is some evidence that RAN is improved by RR. Bowers (1993) in a study involving slow readers from grades 2 to 4 reported improvements in both fluency and RAN after intervention; and Wolff (2014) discovered that RR training led to a significant improvement in both reading speed and RAN. Alternatively, other studies have reported no direct or indirect effect on RAN performance of training to improve reading fluency (for review, Kirby, Georgiou, Martinussen & Parrila, 2010; Norton & Wolf, 2012). Given the inconclusive nature of these findings, further investigation of the possible impact of RR instruction on RAN performance was part of the current investigation (described in Paper 3).

Another widely studied question in the RR literature is whether single-words or passages are more effective training materials. Single-word training using either word lists or individual presentation via flashcards or a computer screen have shown to be effective for reading trained words (Fleisher, Jenkins & Pany, 1979) or connected text that contains trained words (Levy, Abello & Lysynchuk, 1997; Meyer & Felton, 1999; Tan & Nicholson, 1997). At the same time, some previous studies showed that RR for passages of connected text was more effective for enhancing reading fluency (Faulkner & Levy, 1999; Martin-Chang & Levy, 2005; Rashotte & Torgesen, 1985; Therrien & Kubina, 2007), whereas others showed that both types of training were beneficial (Ring, Barefoot, Avrit, Brown & Black, 2013; Therrien et al., 2012). In light of this inconsistent background literature, the current research was designed to shed further light on the question of whether single-words or passages of connected text serve as more effective RR training materials, and whether their effectiveness depends on the way in which reading outcomes are assessed (e.g., through measures of single-word or passage reading fluency).

A final relevant question relates to the effectiveness of RR for improving children's reading comprehension. In this regard, the available evidence is conflicting. Some investigators reported moderate gains in comprehension compared to larger gains in reading speed on trained passages (see Therrien, 2004, for a review), whereas others reported only minimal or inconsistent improvement in reading comprehension (e.g., Levy et al., 1997; Rashotte & Torgesen, 1985). Gains in comprehension often resulted from use of an intervention design that including both RR of connected text and specific treatment of comprehension. Therrien, Wickstrom and Jones (2006) for example, demonstrated improvements in comprehension and reading rate of unfamiliar texts only when RR was accompanied by an additional program designed to assist readers in monitoring their comprehension during the re-reading of the texts. The question of whether RR was effective for improving passage reading comprehension was addressed as part of the third study reported here, through evaluation of generalisation (transfer) effects (see Paper 3).

The Present Investigation

This thesis reports on research conducted into the reading development of early primary- school-aged children, with a particular focus on the assessment and instruction of reading fluency. For purposes of the research, we investigated the indicators of fluency: *accuracy* of word recognition, and *rate* of single-word and passage reading. The research is presented in a series of three papers.

The importance of closely monitoring children's reading development and reading-related skills to incorporate necessary, timely, effective adjustments to classroom practice and/or targeted instruction cannot be overstated. It is vital that such decision-making is supported by strong knowledge of which aspects of reading will provide the most useful information. The study reported in Paper 1 (Chapter 2) investigated the utility of the RAN task for this purpose, as previous research has shown an association between RAN and the development of reading and reading-related skills in typically developing children of primary-school age. Particular to this study, was investigation into the extent to which the strength of the RAN-reading relationship varies according to the nature of the RAN task and the particular aspect of reading ability under consideration in a sample of mixed-ability readers from grades 2 to 4.

The second paper (reported in Chapter 3) extends this issue of timely and appropriate assessment, by investigating the benefit of including the RAN task in a battery of assessments devised to identify children most likely to benefit from targeted instruction for reading fluency. Investigation of the RAN task as a potential screener for profiling reading difficulties in children from grades 2 to 4, was undertaken; with a particular focus on whether RAN would be useful for identifying those children who had poor reading fluency or were at risk of developing poor reading fluency.

Finally Paper 3 (Chapter 4), reports on a study evaluating the effectiveness of RR instruction (using words and passages) for a group of primary-school-age children of mixed-ability who displayed accurate single-word decoding skills and average or below average single-word reading fluency. This research also explored whether the materials used for training (single-words or passages of connected text) would affect the strength of immediate gains (on trained passages) and or transfer effects (generalisation to untrained passages). Such information is vital for classroom teachers and practitioners in assisting them to design effective instructional programs.

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CHAPTER TWO

UNDER WHAT CONDITIONS IS RAN RELATED TO READING … OR NOT?

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Abstract

Previous research has shown an association between reading ability and rapid automatised naming (RAN) in typically developing children of primary-school-age. Typically, RAN is measured by the time taken to name letters, digits, colours, or objects horizontally (row by row). In this research, we explored the association between reading ability and RAN, using a variety of naming tasks in which the nature of the stimuli to be named and the direction of scanning required (horizontal vs. vertical) was manipulated. Participants were 58 native English-speaking Australian students in grades 2-4. Results confirmed previous findings that alphanumeric RAN is an important correlate of reading independent of Phonological Awareness (PA) and Letter-Knowledge (LK) in early primary-aged-children. In particular, RAN performance was associated with exception-word reading accuracy, real and nonword reading fluency, and passage reading rate, both oral and silent. Findings suggest that either vertical or horizontal RAN would be a valuable addition to a diagnostic assessment battery for young children learning to read, although horizontal RAN may be a better indicator of reading fluency for single-words and nonwords.

Introduction

The importance of timely, evidenced-based assessment practice to identify children who may experience difficulty in learning to read has been well established in the literature (Buckingham, Wheldall & Beaman-Wheldall, 2013; Hudson, Lane & Pullen, 2005; Kuhn, Schwanenflugel & Meisinger, 2010; Moats, 1999; Torgesen, 1998). Early detection is crucial for planning and delivery of targeted intervention (Byrne, Fielding-Barnsley & Ashley, 2000; Foorman, Francis, Shaywitz, Shaywitz & Fletcher, 1997; Meisinger, Bloom & Hynd, 2010; Norton & Wolf, 2012; Ozernov-Palchik et al., 2016; Roehrig, Duggar, Moats, Glover & Mincey, 2008). There is considerable evidence that letter-knowledge (LK) and phonological awareness (PA; the ability to reflect on and manipulate the sound structure of language) are strongly associated with early reading success (Duff & Clarke, 2011; Fielding-Barnsley, 2010; Melby-Lervag, Lyster & Hulme, 2012; Muter, Hulme, Snowling & Stevenson, 2004), but poor performance on measures of rapid automatised naming (RAN) is also acknowledged as an additional, independent indicator of current and/or future reading difficulties in children (Denckla & Rudel, 1976; Hulme & Snowling, 2013; Wolf & Bowers, 1999; Wolf, Bowers & Biddle, 2000). As such, the inclusion of LK, PA, and RAN in a battery of reading assessments for young readers should have diagnostic value.

Briefly, RAN refers to the ability to recognise and name quickly and accurately a set of visually presented, highly familiar stimuli (Denckla & Rudel, 1974; Norton & Wolf, 2012). The original RAN task, and the most commonly used, comprises four subtests: object naming, colour naming, digit naming, and letter naming, each with 50 items arranged in 5 rows of 10. Participants are asked to name the randomly ordered stimuli on the page as quickly and accurately as possible from left-to-right and top-to-bottom. The time it takes to complete the task is recorded. Proponents of RAN argue that it is related to reading because both processes depend upon rapid, automatic symbol retrieval. Norton and Wolf (2012) described the RAN task's relation to reading as a "microcosm or mini-circuit of the later-developing reading circuity" (p. 430). In the current research, we sought to enhance understanding of the RAN-reading link in a sample of young (grades 2 to 4), mixed-ability readers through a detailed investigation of the extent to which the strength of the relationship varies according to the nature of the RAN task used and the particular aspect of reading under consideration.

We begin by considering the componential nature of reading and the types of reading difficulty that can result from selective impairment to different component processes. The associations between component reading processes and different versions of the RAN task are then described, with a view to identifying gaps in our knowledge regarding the RAN-reading link.

A model of reading

It has long been accepted that reading comprehension skill is positively associated with oral single-word reading ability (Perfetti & Hogaboam, 1976). According to a dual route model (DRM) of single-word oral reading (e.g., Coltheart, Rastle, Perry, Langdon & Ziegler, 2001), two cognitive processing mechanisms are used simultaneously for converting print to speech: a non-lexical process, which requires the application of grapho-phonic (letter-sound) rules (GPC route); and a lexical process, which involves recognising a word's orthography and retrieving its associated phonological representation directly from memory (lexical route). Furthermore, the efficient operation of these different mechanisms is necessary for reading different types of words. Exception, or irregular, words cannot be pronounced correctly by 'sounding out' because their pronunciations do not follow GPC rules; hence they must be read using the lexical route. On the other hand, nonwords cannot be read lexically as they have no stored orthographic representations in memory; hence, they must be read non-lexically, via the GPC route. Regular words can be read correctly using either route, provided they are known to the reader. As skilled reading performance is exemplified by the ability to read exception words, regular words, and nonwords effortlessly, poor development of either reading mechanism can result in reading difficulties, albeit of different types (e.g., Castles & Coltheart, 1993).

Reading disability subtypes

In the early primary school years, a common source of reading difficulty lies in operation of the GPC route; that is the accurate application of letter-sound rules to pronounce words or nonwords. This type of reading difficulty is known as developmental phonological dyslexia. Standardised measures of LK, PA, and nonword reading allow for relatively straightforward identification of children who are experiencing or at risk of experiencing such decoding difficulties (Melby-Lervag et al., 2012). If children demonstrate decoding problems, phonics instruction, inclusive of explicit, systematic training in the alphabetic principle; that is, knowledge of how printed letters (graphemes) map onto spoken sounds (phonemes), is acknowledged as key to improving their reading skills (Duff & Clarke, 2011; Ehri, Nunes, Stahl & Willows, 2001).

By contrast, some students can be proficient readers of regular and nonwords but demonstrate difficulties in reading exception words, which, according to DRM is a result of inefficiencies in the lexical reading mechanism (developmental surface dyslexia). Readers who demonstrate this type of reading difficulty would not be expected to experience problems with LK or PA, and phonics intervention would not be recommended, since their reading of nonwords is intact. Rather, targeted intervention should promote the establishment of words' orthographic representations in the lexicon; for example, through improving the efficient recognition of common letter patterns in words (e.g., Law & Cupples, 2017).

While the DRM is useful for understanding selective difficulties in oral reading *accuracy*, another aspect of skilled reading is *fluency*. Fluent reading is reflected not only in accurate word decoding but also satisfactory reading speed (Armbruster, Lehr & Osborn, 2001). Since children can be accurate single-word readers but still not display fluent reading skills (Meyer & Felton, 1999), fluency is another aspect of reading ability that needs to be assessed when deciding on instruction and intervention requirements.

How is RAN related to different aspects of reading?

Over the past four decades evidence has emerged for a positive association between RAN and various measures of reading, including accuracy and fluency at the level of single-words and passages. Several theoretical accounts have been proposed to explain this association. The first proposal is that RAN relates to reading because both require efficient and rapid access to, and retrieval of, phonological representations from long term memory (Torgesen, Wagner, Rashotte, Burgess & Hecht, 1997; Wagner & Torgesen, 1987). Whilst a popular theory, it is challenged by evidence that PA and RAN account for independent variance in reading development (Denckla & Rudel, 1976; Wolf & Bowers, 1999; Wolf et al., 2000); that is, even after accounting for variation in LK and PA, measures of RAN have the potential to predict current and future reading outcomes in early readers (Hulme & Snowling, 2013; Kirby, Parrila & Pfeiffer, 2003; Lervag & Hulme, 2009; Norton & Wolf, 2012; Ozernov-Palchik et al., 2016; Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004).

The finding of an independent role for RAN in predicting reading performance has led to a second theoretical proposal, which is exemplified in the “double deficit hypothesis” (DDH) of Wolf and Bowers (1999). According to the DDH early readers can have singular deficits in either PA or RAN, or a “double deficit” in both, with this latter group being the most impaired of all in terms of reading fluency.

Related to, and consistent with the DDH, are findings suggesting that the RAN-reading link is due to a shared association with orthographic processing (Bowers, Golden, Kennedy & Young, 1994; Bowers & Newby-Clark, 2002; Bowers & Wolf, 1993; Clarke, Hulme & Snowling, 2005; Manis, Doi & Bhadha, 2000). For example, Bowers et al. (1994) hypothesised that children who are slow to identify the individual letters contained in printed words, may fail to activate those letters simultaneously in memory, thus creating difficulties for the establishment of orthographic patterns and orthographic representations of words. Since fluent reading relies on the accurate and rapid recognition of words in text, orthographic knowledge, demonstrated by quickly and accurately recognising letter patterns in words, is an obvious contributor to single-word and passage reading fluency (Barker, Torgesen & Wagner, 1992; Ehri, 2005; Perfetti, 1992).

Evidence supporting the proposed association between RAN and orthographic processing comes from a study by Manis et al. (2000). In a sample of 85 grade 1 and 2 students, they found that measures of PA accounted for nonword reading ability, while measures of RAN (for letters and digits) explained unique variance in exception word reading after controlling for PA and vocabulary knowledge. They also demonstrated that children with poor RAN skills did poorly in choosing a word's correct spelling from a word/nonword pair (orthographic choice). This latter finding was replicated in a study by Conrad and Levy (2007) who attributed it to a difference in print exposure as suggested by the earlier work of Cunningham and Stanovich (1993). Finally, a consistent pattern of results was reported by Clarke et al. (2005) who found that RAN accounted for independent variance in exception word reading after controlling for PA in a sample of 30 children, ages 8-11.

A fourth and final theory regarding the association between RAN and reading attributes the link to a common association with processing speed; that is, because both fluent reading and rapid naming require speed for efficient performance (e.g., Kail & Hall, 1994). Abu-Hamour, Urso and Mather (2012) investigated this possibility in a study involving 56 children, ages 6 to 10. Their results showed that exception word reading was more strongly associated with processing speed than with RAN, although the difference was not significant.

On the other hand, nonword and word reading performances were more strongly associated with RAN than with processing speed, but again the differences were not significant. Nevertheless, the authors interpreted their results as showing that RAN and processing speed predict *different* aspects of word reading. If so, the RAN-reading link is unlikely to result solely from the two tasks' common association with processing speed. Abu-Hamour et al. also found that RAN was more strongly associated with timed than untimed nonword reading performance, although the significance of this difference is not reported in the paper.

To this point, we have considered the association between RAN and reading primarily from the perspective of single-words. An equally important question is how RAN relates to reading ability in terms of accuracy, rate, and comprehension for multiple words and passages of text (Bowers, 1993; Lervag & Hulme, 2009; Savage & Frederickson, 2005). Savage and Frederickson investigated the association between RAN and passage reading rate in 67 10-year-olds, the majority of whom were poor readers. Using multiple regression analyses to control for variation in vocabulary and nonword reading, they found that both RAN and PA accounted for unique variance in passage reading accuracy, whereas only RAN predicted reading rate, and PA predicted comprehension. Additional relevant evidence comes from a 3-year longitudinal study by Lervag and Hulme (2009). Results from 233 children revealed that RAN measured in the year prior to reading instruction predicts later text reading fluency. More recently, Papadopoulos, Spanoudis and Georgiou (2016) investigated how RAN is related to oral and silent reading fluency. A sample of 286 Greek-speaking students in grades 1 and 2 completed various assessments including a measure of oral reading rate for words and nonwords (number correct in one minute), and a measure of silent reading rate, in which participants were given one minute to identify word boundaries from within a continuous line of print (e.g., *bookgoodlight*). Findings suggested that RAN predicted oral reading fluency but not silent reading fluency. In accordance with Georgiou, Parrila, Cui and

Papadopoulos (2013), the researchers inferred that articulation was necessary for there to be an association between RAN and reading.

To summarise, previous studies provide evidence that RAN is a predictor of single-word reading abilities in primary-aged students, independent of both LK and PA (e.g., Hulme & Snowling, 2013). More specifically, RAN is positively associated with orthographic processing skill as reflected in exception word reading accuracy and orthographic choice tasks (Clarke et al., 2005; Conrad & Levy, 2007; Manis et al., 2000). There is also some evidence that RAN is more strongly associated with timed than untimed word reading tasks (Abu-Hamour et al., 2012) and with oral rather than silent reading (Papadopoulos et al., 2016). In regard to passage reading, the association with RAN appears to be stronger for measures of oral reading fluency, in terms of rate (Lervag & Hulme, 2009; Savage & Frederickson, 2005), than for comprehension.

This brief interim summary of previous findings illustrates that the RAN-reading link varies as a consequence of the component reading process being investigated. Another important variable to consider is the nature of the task used to assess RAN. Past research has explored aspects of RAN such as the nature of stimuli (objects, colours, letters and digits), and their format (e.g., serial vs. discrete presentation, and direction of scanning). The crucial question is whether all RAN tasks are associated equally with the different aspects of reading, implying that a common underlying component is responsible for all associations (e.g., rapid automatic symbol retrieval); or whether some tasks (e.g., those with alphanumeric stimuli to be named in a left-to-right and top-to-bottom format) are more closely associated with some (or all) aspects of reading because they share specific component processes (e.g., left-to-right and top-to-bottom scanning).

Nature of stimuli in the RAN task

An important distinction in the RAN literature relates to the use of alphanumeric (letters, digits) or non-alphanumeric (e.g., objects, colours) stimuli. One advantage of using non-alphanumeric stimuli is that children can be assessed *prior* to school entry. Importantly, some evidence suggests that, when measured in the year prior to reading instruction, non-alphanumeric RAN predicts children's later text reading fluency (Lervag & Hulme, 2009). However, beyond kindergarten, and especially once children begin to learn to read, research suggests that the diagnostic value of the RAN task is enhanced through the use of alphanumeric stimuli (Clarke et al., 2005; Katzir et al., 2006; Lervag & Hulme, 2009; Misra, Katzir, Wolf & Poldrack, 2004; Wolf, Bally & Morris, 1986).

With respect to the aspects of reading that are most closely associated with alphanumeric RAN, Savage and Frederickson (2005) reported that once vocabulary was controlled, RAN-digits was a stronger predictor of passage reading rate than either rhyme detection or nonword reading. Furthermore, in interpreting their findings, the researchers concluded that the association was attributable to the alphanumeric nature of the RAN stimuli, because a similar association was not significant using RAN for objects.

Other studies confirm that alphanumeric RAN is a stronger predictor of reading skills than non-alphanumeric RAN. For example, Compton (2003) assessed 75 grade 1 students on seven occasions throughout the school year and found that RAN-digits was a stronger predictor of reading than RAN-colours; and more specifically, that RAN-digits explained unique variance in word and nonword reading accuracy while RAN-colours did not. Interestingly this study also revealed that as decoding performance of participants improved, so too did their RAN performance, thus suggesting a *bidirectional relationship* between RAN and reading.

In addition to reported differences between alphanumeric and non-alphanumeric RAN, some studies have shown that the RAN-reading link can vary according to the type of alphanumeric stimuli used. Neuhaus, Foorman, Francis and Carlson (2001), reported that RAN-letters was a stronger predictor of single-word reading accuracy and passage comprehension than either RAN-objects or RAN-digits in their sample of 50 students from grades 1 and 2. Similarly, Abu-Hamour et al. (2012) proposed that RAN-letters was more strongly associated with reading performance than other RAN tasks, including RAN-digits. Interestingly, both Neuhaus et al. and Abu-Hamour et al. suggested that the RAN-reading associations they observed were due in part to the need for efficient left-to-right scanning in both tasks, an issue to which we return below.

By contrast, with the majority of published research examining the nature of the stimuli used in RAN tasks, Clarke et al. (2005) found that RAN for digits but not letters was a significant predictor of exception word reading accuracy after controlling for variation in phonemic awareness. Furthermore, some past studies found evidence of an association between non-alphanumeric RAN and reading in children beyond kindergarten. Papadopoulos et al. (2016) reported that for children in grades 1 and 2 either version of the RAN task (alphanumeric or non-alphanumeric) predicted oral word reading fluency but not silent word reading fluency. Kruk, Mayar and Funk (2014) tracked a sample of 52 at-risk readers and 69 not-at-risk readers from grade 1 through to grade 3, and identified that RAN (for objects and colours) measured in grade 1 predicted later ability to read exception words.

In summary, the studies reviewed here indicate that once instruction in reading has begun, alphanumeric RAN (for letters or digits) is generally more closely associated with reading performance than non-alphanumeric RAN (Lervag & Hulme, 2009; Misra et al., 2004), and RAN for letters is typically more closely associated with reading measures than RAN for digits (e.g., Abu-Hamour et al., 2012; Neuhaus et al., 2001). There are, however, several exceptions to these generalisations (e.g., Clarke et al., 2005; Kruk et al., 2014; Papadopolous et al., 2016), thereby justifying further detailed investigation.

Direction of scanning in the RAN task

A second important question with regard to the RAN-reading association is the extent to which it reflects the serial nature of the traditional RAN task; and in particular, the requirement for participants to name stimuli row-by-row (from left-to-right and top-to-bottom) (Bowers & Swanson, 1991; Georgiou et al., 2013; Logan, Schatschneider & Wagner, 2011). If the link between RAN and reading lies in the learned, directional processing of written words and text, which is equivalent to the left-to-right scanning required in traditional RAN tasks (Protopapas, Altani & Georgiou, 2013b), it would stand to reason that a weaker correlation should be evident if the RAN task were presented in a different format.

In accordance with this view, Norton and Wolf (2012) proposed that certain factors are fundamental to the theoretical link between RAN and reading and therefore must be maintained: in particular, suitable familiarity with the items to be named, and naming in a serial, left-to-right fashion. They cited supporting evidence to indicate that a strong relationship between RAN and reading would hold only when the RAN task was presented in a traditional serial format, rather than a discrete format in which participants name stimuli that are presented individually, often on a computer screen.

Further investigation of this proposal was conducted by Protopapas et. al (2013b) in a study involving 107 grade 6 children. Measures of word reading and passage reading fluency were included along with measures of RAN (digits and objects), which were presented in standard serial format (left-to-right) and in a backward direction (i.e., participants were asked to begin naming at the bottom right corner and working from right-to-left and bottom-to-top). Protopapas et al. proposed that if RAN and reading were associated due to both requiring left-to-right and top-to-bottom scanning, then RAN-backwards would show a weaker association with reading. Results demonstrated that, whilst not significant, correlations between RAN-backwards and reading were larger than those between reading and the traditional RAN task. Furthermore, Protopapas et al.'s findings were not reliant on the use of similar formatting in the reading and RAN tasks; that is, the association between RAN and reading was also evident for a measure of word-reading fluency presented in a column format (i.e., requiring top-to-bottom reading) and RAN measures presented backwards. Such findings suggest that the common need for left-to-right visual scanning cannot fully explain the RAN/reading link.

While considerable research has addressed the question of whether the format in which the RAN task is presented affects its association with reading, the same cannot be said for the assessment of reading, where presentation format has been largely neglected. de Jong (2011) addressed this gap in the literature with a study of 272 Dutch children from grades 1, 2, and 4. Assessments included serial (words presented in a list) and discrete reading of one-syllable, high frequency words, and a standardised test of word and nonword fluency comprising a four-column format, in which children read from top-to-bottom. de Jong hypothesised that if high frequency words are read lexically (i.e., by sight, with letters processed in parallel), then correlations with discrete RAN should be evident because both tasks involve a lexical process of retrieving an associated phonological representation from memory.

By contrast if high frequency words are read non-lexically (via serial, letter-by-letter decoding) a stronger correlation with serial RAN should be evident because both tasks involve a serial process. Findings showed that for beginning readers (grade 1), serial RAN was more strongly associated with reading of high frequency words and nonwords regardless of their presentation format. By contrast, word reading in grades 2 and 4 was dependent on the format of both measures; that is, discrete RAN was more strongly correlated with discrete reading of high frequency words than with serial reading of those words; and serial RAN was more strongly associated with serial than discrete reading of high frequency words. A subsequent study by Protopapas, Altani, and Georgiou (2013a) confirmed this general pattern of RAN-reading associations in a sample of older (grade 6) Greek-speaking children; and Zoccolotti et al. (2013) reported an advantage for serial over discrete formats in both RAN and word reading assessments in a group of 11-year-old Italian-speaking children with typical reading development.

In summary, the literature suggests a stronger relationship between reading and serial RAN than the discrete format, and possible differential links to specific aspects of reading, which require further investigation. For instance, following on from work by de Jong (2011), the question arises as to whether efficiency in lexical or non-lexical reading strategies (as utilised in reading exception words and nonwords respectively) might be differentially associated with RAN tasks presented in different formats. The current study builds on past research by examining further the influence of task format on RAN's association with reading. To our knowledge no previous investigation has compared the traditional serial RAN task, in which stimuli are named row-by-row (left-to-right, horizontal; hereafter RAN-H), with a non-traditional, but still serial task in which stimuli are named column by column (left-to-right, vertical; hereafter RAN-V). Such investigation is important in providing further information as to which RAN formats are associated with which aspects of reading; and to what extent the RAN-reading relationship depends on the *serial* nature of RAN per se, and/or its traditional reliance on *left-to-right* scanning.

The current study

While much evidence supports the notion that RAN provides additional, vital information regarding children's reading performance over and above that provided by PA and LK (Denckla & Rudel, 1976; Hulme & Snowling, 2013; Wolf & Bowers, 1999; Wolf et al., 2000), interpretation of the association between RAN and reading is debated in the literature. The current study was devised to shed further light on this relationship. To do so, we investigated the association between RAN tasks that varied with respect to the stimuli to be named and their presentation format, and different aspects of reading. These associations were examined in a group of mixed-ability children in grades 2 to 4 after controlling for the potentially confounding influence of variation in age, PA, and LK.

Previous results showed that alphanumeric RAN is typically more strongly correlated with reading than non-alphanumeric RAN (Clarke et al., 2005; Savage & Frederickson, 2005). However, many past studies examined only one or two subtests within the RAN task itself; such as digit and picture naming (Savage & Frederickson, 2005); digits and colours (Compton, 2003); or even a single subtest such as digits (Bowers, 1993). In the current study all sub-tests of RAN (objects, colours, digits and letters) were investigated for their association with reading. In addition, the various RAN sub-tests were presented in two different formats. Both involved serial processing of RAN stimuli, but in one version, participants named stimuli row-by-row (horizontally; RAN-H) as in the original RAN task developed by Denckla and Rudel (1976), whereas in the second version, stimuli were named column-by-column (vertically; RAN-V). Whilst several past studies have compared serial RAN with a discrete presentation format, to our knowledge no previous investigation has compared horizontal with vertical RAN.

Finally, to establish the nature of any specific associations between RAN tasks in various formats and particular aspects of reading ability, a wide range of reading measures and materials was used. They included: oral reading accuracy for individually presented exception words and nonwords; oral reading fluency for lists of real words (both exception and regular) and nonwords; silent word reading (orthographic choice); oral passage reading (accuracy, rate, and comprehension); and silent passage reading (rate and comprehension).

Research questions and hypotheses

The overarching question addressed in this research was whether the association between RAN and reading would vary according to the nature of the RAN task and/or the aspect of reading under consideration. More specifically, we asked the following questions.

1. Would the RAN-reading association differ according to the type of stimuli to be named in the RAN task (i.e., alphanumeric vs. non-alphanumeric)? If so, would all reading measures show a similar pattern of results?

2. Would the RAN-reading association differ according to the direction of scanning required in the RAN task (i.e., horizontal vs. vertical)? If so, would all reading measures show a similar pattern of results?

3. Would the RAN-reading association differ according to the reading measures used?

As regards research question 1, based on previous reported studies of children in a similar age bracket, we expected that after controlling for variation in age, PA, and LK, our findings would confirm a difference in the RAN-reading association according to the type of stimuli to be named. More specifically, we expected that alphanumeric RAN would be more strongly associated with all reading measures than non-alphanumeric RAN (Bowers, 1993; Clarke et al., 2005; Savage & Frederickson, 2005). With respect to the second research question, we expected that the RAN-reading association would differ according to the direction of scanning required in the RAN task (as per Norton and Wolf, 2012). In this case, however, we hypothesised that all measures of reading might not reveal the same pattern of results. In particular, RAN-H may be more closely associated with students' ability to read passages of text and single nonwords (which involve left-to-right serial processing of component letters and sounds); whereas RAN-V may be more closely linked to exception word reading (which involves parallel processing of constituent letters), and orthographic knowledge, as reflected in the ability to make correct orthographic choices. RAN-V may also be more closely associated with performance on the list-based single-word reading task included here, in which participants must read column-by-column, just as they do in RAN-V (de Jong, 2011; Protopapas et al., 2013a).

Finally, in regard to research question 3, we predicted that the RAN-reading association would differ according to the reading measures used. More specifically, on the basis of previous research, we expected RAN to be more closely associated with oral than silent reading fluency (e.g., Papadopolous et al., 2016), passage reading rate rather than accuracy or comprehension (e.g., Savage & Frederickson, 2005), and with exception word reading than nonword reading (e.g., Clarke et al., 2005).

Method

Participants

This study formed part of a larger investigation into children's reading fluency. The initial participant sample comprised 74 native English-speaking Australian students in grades 2-4 from an independent school within a medium socio-economic area. However, 16 of these students were omitted prior to data analysis: one who left the school during the data collection phase, and 15 who failed to meet the inclusion criterion of a nonverbal IQ > 80. Consequently, data reported here were collected from a final sample of 58 students (32 males and 26 females), which included 11 children from grade 2, with a Mean age of 7 years; 6 months (7;6), 30 from grade 3 (Mean age = 8;6), and 17 from grade 4 (Mean age = 9;6). The participants met the following additional inclusion criteria of: (1) normal hearing; (2) normal or corrected-to-normal vision; (3) no known history of learning difficulties; and (4) English as the home language (although one child also spoke a second language at home). A previous diagnosis of attention deficit/hyperactivity disorder (ADHD) was not an exclusion criterion for this study.

Caregivers provided informed consent and relevant background information was collected in the form of a parental survey. Items included participants' age; caregivers' level of education; languages spoken at home; previous referral to a speech pathologist; and intervention received at school for learning difficulties (either participant or family members). Caregivers reported that 9 out of 58 of the participants had received intervention at school for learning difficulties and/or had been referred to a speech pathologist. Prior intervention for learning difficulties at school was reported by 16 caregivers for either themselves or an additional child. Information indicated that caregivers were generally well-educated, with all but 3 having 13+ years of education. Caregivers also reported participating in reading activities with their children, either school-related or for leisure, several times per week. At the conclusion of data collection, each caregiver was provided with a report of their own child's results.

Measures

A combination of standardised and non-standardised assessments was used to measure the experimental variables of RAN and reading; the control variables of non-verbal cognitive ability, PA, and alphabet knowledge; and the background variables of phonological memory, receptive vocabulary, and syntactic ability. All sessions were audio-recorded for later transcription, scoring, validity, and reliability purposes.

RAN measures

RAN was assessed using four subtests from Wolf and Denckla's (2005) Rapid Automatised Naming and Rapid Alternating Stimulus (RAN/RAS) assessment. Digit naming and letter naming were used to assess alphanumeric RAN, whereas object naming and colour naming were used to assess non-alphanumeric RAN. All RAN tasks comprised 50 items arranged in 5 rows of 10, and were preceded by 2 rows of 5 items for practice. Participants were asked to name the randomly ordered stimuli on the page as quickly and accurately as possible while the experimenter used a stopwatch for timing purposes. In RAN-H they were instructed to name the stimuli from left-to-right and top-to-bottom as per the standardised instructions. In RAN-V they received non-standard instructions, and were asked to name the stimuli from top-to-bottom and left-to-right in a vertical pattern. This instructional manipulation meant that standard scores could not be assigned for RAN-V. Thus, to enable direct comparison of the results for RAN-H and RAN-V, raw scores (calculated as the number of seconds taken to name all 50 items in each subtest) were used for analysis purposes.

Reading outcome measures

Word reading accuracy.

Oral reading accuracy for single-words (regular and exception) and nonwords was assessed using the Coltheart and Leahy Reading Test (1996). Participants were presented with 30 items of each word type, printed on individual cards, and asked to read each one aloud. No time limit was imposed. Raw scores (calculated as the number of regular words, exception words, and nonwords read correctly out of 30) were used for analysis purposes.

A second measure of word reading accuracy was used to assess students' knowledge of orthography. In this silent reading task, participants were presented with 52 word/nonword pairs (e.g., bark / barc) from the Orthographic Choice Task (Olson, Wise, Conners, Rack & Fulker, 1989) and asked to point to the real word from each pair. Since both items within each pair had the same pronunciation when decoded using letter-sound rules, knowledge of word-specific orthography was necessary to respond correctly. Raw scores (calculated as the number of correctly selected real words out of 52) were used for analysis purposes.

Word and nonword reading fluency.

Oral reading fluency for single-words and nonwords was assessed using the Test of Word Reading Efficiency – Second edition (TOWRE-2; Torgesen, Wagner & Rashotte, 2012). This test contains two subtests. Sight word efficiency (SWE) measures participants' ability to read words as whole orthographic units; whereas phonemic decoding efficiency (PDE) measures the ability to use grapho-phonic (letter-sound) knowledge to decode unfamiliar letter strings. In both subtests, participants are presented with lists of words (in the SWE) or nonwords (in the PDE) arranged in vertical columns. They are asked to read down the columns, reading aloud as many items as they can in a 45-second period, both quickly and accurately. Practice lists of 8 words and 8 nonwords are completed prior to the test proper. When combined these two subtests provide a Total Word Reading Efficiency (TWRE) score. In the current study, a stopwatch was used for timing purposes, and raw scores (calculated as the number of words or nonwords read correctly within the allocated time) were converted to standard scores (distributed with a mean of 100 and standard deviation of 15) for analysis purposes.

Passage Reading - accuracy, rate and comprehension.

Oral reading of passages was assessed using the standard version of the Neale Analysis of Reading Ability – Third Edition (NARA-3; Neale, 1999). Participants were assessed according to instructions in the test manual. Time taken to read each short passage aloud is recorded using a stopwatch, but with no time limit was imposed. The standard version (Form 1) contains six passages of increasing difficulty. Students continue reading through each passage of increasing difficulty until 16 oral reading errors are made in a single passage. Raw Scores and percentile ranks for accuracy, speed, and comprehension, were calculated according to instructions in the test manual.

For the purpose of this study a second passage reading task was devised and administered using additional matched passages from the NARA-3 (Neale, 1999). In this non-standard version students were timed as they read each passage silently, with no limit imposed. Raw scores (calculated as words read per minute and number of correct answers to comprehension questions) were used for analysis purposes. Once a participant made more than three errors on the comprehension questions for a given passage, testing ceased.

Control Tasks

Three assessments were administered to control for variation in children's PA, alphabet knowledge, and non-verbal IQ, all of which might influence their performance on the reading and reading-related tasks of primary interest. Whereas PA and alphabet knowledge were controlled statistically, non-verbal IQ was controlled by including only participants with an IQ of 80 or above.

PA.

PA was assessed using the Comprehensive Test of Phonological Processing – Second edition (CTOPP-2; Wagner, Torgesen & Rashotte, 2013*).* Three core tests were used: Elision (EL), in which participants are asked to remove phonological units from words to make other words; Blending Words (BW), in which participants are asked to combine sounds to form words; and Phoneme Isolation (PI), in which participants isolate individual sounds within words. For all subtests, testing was discontinued after three consecutive incorrect responses. Raw scores (calculated by adding the number of correct responses) were obtained, from which standard scores (distributed with a mean of 100 and standard deviation of 15) were computed and used for analysis purposes.

Alphabet knowledge.

Alphabet knowledge was assessed using the NARA-3 (Neale, 1999). Participants were asked to say the sound made by each of the 26 letters of the English alphabet, presented in random order and lower-case form. As this measure was non-standardised raw scores (calculated as the number of correct responses out of 26) were used for analysis purposes.

Non-verbal Cognitive ability.

The 2-subtest form of the Wechsler Non-verbal Scale of Ability (WNV; Wechsler & Naglieri, 2006) was administered according to instructions in the test manual to assess non-verbal cognitive ability. All participants completed the matrices subtest, in which they were asked to choose one possibility from a range of pattern pieces to correctly complete an incomplete grid. Additionally, dependant on age, participants either completed the recognition subtest (up to 7;11) or the spatial span sub–test (8;0 and above). Full scale scores (distributed with a mean of 100 and standard deviation of 15) were computed for purposes of participant inclusion.

Background measures

Phonological memory.

The Memory for Digits subtest from the CTOPP-2 (Wagner et al., 2013) was used to assess participants' phonological short-term memory. In this subtest, children are required to repeat verbatim orally presented number sequences that gradually increase in length. Testing is discontinued after three consecutive incorrect responses. Raw scores were obtained by adding the number of correct responses out of a possible 28, from which standard scores were derived (distributed with a mean of 10 and standard deviation of 3). Standard scores were used in the current study for description and analysis.

Receptive vocabulary.

The Peabody Picture Vocabulary Test - Fourth Edition (PPVT-4; Dunn & Dunn, 2007) was used to obtain a measure of children's receptive vocabulary. On each trial, children are presented with a set of pictures, four to a page. The examiner utters a word that describes one of the pictures, wherein the examinee is asked to point to the picture that best represents the spoken word. In the current study, raw scores (number of correctly identified pictures) were used to obtain standard scores, distributed with a mean of 100 and standard deviation of 15, which were used for descriptive and analysis purposes.

Syntactic ability.

Syntactic ability was assessed using the Test of Language Development 4 (TOLD-4; Newcomer & Hammill, 2008). Three subtests were used for this purpose. *Syntactic Understanding (SU)* assessed students' ability to comprehend spoken sentences. Participants were provided with a spoken sentence and asked to choose from 3 given pictures the one that matched most closely. *Sentence Imitation (SI)* assessed the ability to organise information by imitating English sentences; and *Morphological Completion (MC)* assessed the ability to recognise and understand the structure of words, and to use parts of words, with particular emphasis on the use of prefixes and suffixes, to complete sentences.

For all subtests, testing is discontinued after five consecutive incorrect responses. Raw scores were obtained by tallying the number of correct responses. Standard scores can be calculated for participants from ages 4.0 through to 8.11; however only raw scores were computed for this study as many participants were beyond this age range.

General Procedure

All sessions took place in a quiet room during school hours at the children's school (described previously). Participants were assessed individually after obtaining written permission from all parents and carers. Approval for the research was granted by Macquarie University Human Research Ethics Committee. The first author (who was the sole examiner) visited children's classrooms to introduce herself to students prior to conducting individual testing; and, together with the classroom teacher, provided an explanation about what students would be asked to do during the session.

Statistical analysis

Correlational analysis was used to address the research questions. More specifically, partial correlations were computed to evaluate the association between different versions of the RAN task and different measures of reading while controlling for variation in age (in years), alphabet knowledge, and PA. Given the large number of correlations conducted, a conservative type 1 error rate of .01 was adopted.

Results

Participant Characteristics

Table 1 contains a summary of the characteristics of the final sample of 58 included participants according to grade. Means and standard deviations are provided for each measure, along with the results from an analysis of variance (ANOVA) comparing children's performance across grades. To compensate for the use of multiple comparisons, a Type 1 error rate of .003 was used (.05 divided by 16). Standard scores are reported for the PPVT and the CTTOP PA and digit memory tasks. At all grade levels, children performed within one SD of the typical mean on average, and no significant difference between grade levels was observed (see Table 1). Raw scores are reported for the remaining variables. Despite the significant difference in age between children in grades 2 to 4 ($F = 60.55$, $p < .001$), only four other significant differences emerged: Children's RAN-H for objects and digits improved from grades 2 to 4, as did RAN-V for objects. A significant improvement was also observed in children's morphological awareness on the TOLD-4 (see Table 1).

Table 1. Participant characteristics: mean scores for RAN and background variables according to grade

	Grade							
	2		3		4		*F*	*p*
No. participants (males)	11 (9)		30 (15)		17 (8)		n/a	n/a
Age (years)	7.6	(0.44)	8.7	(0.41)	9.7	(0.84)	60.55	<.001
NARA Letter sounds (raw)	25.1	(1.14)	22.8	(5.02)	23.6	(2.57)	1.43	.248
CTOPP (SS)								
PA	96.1	(9.44)	95.5	(15.20)	95.6	(13.05)	<1	.993
Memory for digits	9.7	(3.13)	9.8	(3.13)	10.4	(3.10)	<1	.794
RAN – H (raw)								
Objects	58.7	(13.84)	48.1	(7.43)	44.9	(8.36)	7.97	.001
Colours	63.6	(14.77)	52.7	(19.68)	48.8	(11.49)	2.71	.076
Digits	40.9	(9.30)	32.2	(6.60)	29.5	(6.96)	8.65	.001
Letters	38.3	(10.85)	31.7	(8.95)	27.4	(5.15)	5.59	.006
RAN-V (raw)								
Objects	52.5	(8.34)	43.7	(8.02)	41.3	(7.46)	7.21	.002
Colours	61.1	(15.33)	51.2	(20.46)	45.7	(11.07)	2.65	.080
Digits	39.8	(8.78)	33.3	(8.16)	29.9	(8.63)	4.64	.014
Letters	37.1	(9.24)	31.9	(6.50)	28.9	(5.88)	4.71	.013
PPVT (SS)	114.1	(12.72)	107.7	(12.35)	103.2	(10.51)	2.78	.071
TOLD (raw)								
Syntactic understanding	24.6	(2.87)	26.3	(1.82)	25.6	(2.34)	2.25	.115
Sentence imitation	20.7	(6.63)	24.9	(6.80)	26.5	(6.14)	2.629	.081
Morphological awareness	23.1	(4.09)	28.1	(4.55)	30.2	(2.40)	10.95	<.001

Note. Type I error rate set at $\alpha = .003$ (.05 divided by 16) to compensate for multiple comparisons.

Table 2 shows the mean scores and SDs on reading assessments according to grade, along with the results of ANOVAs comparing children's performance across grades. To compensate for the use of multiple comparisons, a Type 1 error rate of .005 was adopted here (.05 divided by 10). Once again, the results show little evidence of significant improvement across grades, except for an increase in children's oral reading accuracy for exception words on the Coltheart and Leahy (1996) assessment.

Table 2. Mean scores (and SDs) on reading assessments according to grade

	Grade						Statistics	
	2		3		4		*F*	*p*
Coltheart & Leahy								
Nonwords	21.3	(5.68)	19.4	(8.54)	21.8	(5.54)	<1	.510
Exception words	15.7	(5.55)	18.2	(4.45)	21.4	(3.10)	6.07	.004
TOWRE-2 (raw)								
SWE	52.1	(16.40)	58.7	(13.33)	65.6	(10.10)	3.64	.033
PDE	23.5	(9.66)	25.0	(13.55)	29.2	(11.02)	<1	.404
Orthographic choice (raw)	33.8	(7.64)	38.5	(5.99)	41.1	(4.91)	4.88	.011
NARA								
Accuracy	40.5	(16.65)	48.0	(21.99)	57.7	(17.58)	2.68	.078
Rate	60.5	(22.59)	73.3	(21.39)	83.0	(22.36)	3.55	.035
Comprehension	14.5	(5.22)	18.3	(8.07)	23.4	(8.16)	4.87	.011
NARA Silent								
Rate	91.3	(61.31)	150.2	(73.72)	163.4	(72.5)	3.74	.030
Comprehension	9.0	(4.67)	14.0	(7.59)	16.9	(8.64)	3.71	.031

Note. Type I error rate set at $\alpha = .005$ (.05 divided by 10) to compensate for multiple comparisons.

RAN and Reading

Table 3 summarises the inter-correlations between the various measures of RAN used in the study. Correlation coefficients above the diagonal are all zero order; whereas those below the diagonal are partial correlations, controlling for age in years, PA, and LK. As noted earlier, a conservative Type 1 error rate of .01 was adopted for all correlational analyses, in light of the large number of correlations conducted. Only two of the correlations between RAN measures failed to reach significance using this stringent criterion; namely, the correlation between RAN-H for digits and RAN-V for colours (r = .33); and that between RAN-V for colours and RAN-V for letters (r = .34). Despite the moderate to large correlations reported in Table 3, the results show clearly that the various RAN measures do not overlap completely.

Table 3. Pearson's product moment partial correlations between different measures of RAN while controlling for age, PA, and letter sound knowledge

		Horizontal				Vertical			
		Objs.	Cols.	Digits	Ltrs.	Objs.	Cols.	Digits	Ltrs.
Horizontal	Objects	1.0	.70**	.60**	.57**	.75**	.62**	.64**	.64**
	Colours	.65**	1.0	.64**	.65**	.74**	.75**	.61**	.50**
	Digits	.54**	.59**	1.0	.76**	.59**	.39*	.77**	.69**
	Letters	.49**	.59**	.72**	1.0	.54**	.59**	.71**	.71**
Vertical	Objects	.76**	.77**	.58**	.51**	1.0	.77**	.73**	.65**
	Colours	.58**	.76**	.33	.54**	.73**	1.0	.52**	.46**
	Digits	.61**	.60**	.78**	.69**	.67**	.42**	1.0	.88**
	Letters	.59**	.44**	.68**	.68**	.58**	.34	.85**	1.0

Note. * = $p < .01$; ** = $p < .001$

Focusing on the partial correlations in particular, shared variance ranged from a low of 10.9% (for the association between RAN-H for digits and RAN-V for colours) to a high of 72.3% (for the association between RAN-V for digits and RAN-V for letters). The results from these partially overlapping RAN tasks were used to address three research questions in regard to the RAN-reading association.

Alphanumeric versus Non-alphanumeric Stimuli in RAN

The first research question was whether the RAN-reading association would differ according to the type of stimuli to be named in the RAN task (i.e., alphanumeric vs. non-alphanumeric); and if so, whether all reading measures would show a similar pattern of results. To shed light on this question partial correlations between the various alphanumeric and non-alphanumeric RAN measures and measures of single-word and passage reading are presented in Tables 4 and 5. The pattern of results is clear in showing no significant association between non-alphanumeric RAN and any measure of reading, either single-word or passage. By contrast, alphanumeric RAN is associated with both single-word reading ability (in particular, exception-word reading accuracy), orthographic choice, word and nonword fluency, and passage reading rate (see Tables 4 and 5).

Table 4. Pearson's product-moment partial correlations between single-word reading measures and RAN according to stimulus type and scanning direction (controlling for age, PA and letter sound knowledge)

		Accuracy (C&L)		Orth. choice	Fluency (TOWRE-2)	
		Exc. words	Nonwords		Words	Nonwords
		Alphanumeric				
Horizontal	Digits	.44**	.23	.36*	.44**	.43**
	Letters	.31	.23	.30	.42**	.41*
Vertical	Digits	.36*	.15	.32	.28	.29
	Letters	.36*	.14	.38*	.30	.33
		Non-alphanumeric				
Horizontal	Objects	.31	-.02	.24	.22	.05
	Colours	.28	.14	.20	.25	.23
Vertical	Objects	.31	-.02	.22	.17	.03
	Colours	.19	.07	.10	.14	.10

Note. * = $p < .01$; ** = $p < .001$

Table 5. Pearson's product-moment partial correlations between passage reading measures and RAN according to stimulus type and scanning direction (controlling for age, PA and letter sound knowledge)

		Oral reading			Silent reading	
		Accuracy	Rate	Comprehension	Rate	Comprehension
		Alphanumeric RAN				
Horizontal	Digits	.34	.55**	.35*	.41*	.33
	Letters	.29	.41*	.14	.22	.03
Vertical	Digits	.27	.37*	.14	.28	.15
	Letters	.30	.36*	.17	.36*	.09
		Non-alphanumeric RAN				
Horizontal	Objects	.12	.20	.14	.21	-.03
	Colours	.24	.29	.18	.19	.18
Vertical	Objects	.13	.31	.11	.23	.10
	Colours	.11	.19	.05	.04	.05

*Note. * = $p < .01$; ** = $p < .001$*

Direction of Scanning in RAN

The second research question was whether the RAN-reading association would differ according to the direction of scanning required in the RAN task (i.e., horizontal vs. vertical); and if so, whether all reading measures would show a similar pattern of results. As shown in Table 4, the RAN-reading association varies according to direction of scanning in the RAN task; in particular, measures of sight-word and nonword fluency (on the TOWRE-2), were both related to RAN-H for digits and letters, but not to RAN-V. Notably, this clear distinction between RAN-H and RAN-V as correlates of reading was not evident for any other reading measures; in particular, both RAN-H and RAN-V were associated with exception word reading accuracy and orthographic choice (see Table 4) as well as oral and silent passage reading rate (see Table 5).

The RAN-Reading Association for Different Reading Measures

The third and final research question was whether the RAN-reading association would differ according to the reading measures used. From the data presented in Table 4, it is evident that alphanumeric RAN is correlated with exception word reading accuracy and orthographic processing (in the orthographic choice task), but *not* with the ability to accurately decode nonwords in an untimed task, as per the Coltheart and Leahy (1996) reading assessment. Furthermore, the data in Table 5 reveal that passage reading rate, both oral and silent, is associated with alphanumeric RAN performance, whereas passage reading accuracy is not, and passage comprehension is weakly associated at most. In summary then, the current results indicate that assessing for RAN provides specific information in terms of performance in exception word reading accuracy, orthographic processing, and reading rate for single-words (e.g., as in the TOWRE-2 assessment) and passages of text, both oral and silent.

Discussion

The primary aim of this study was to investigate the extent to which the strength of the RAN-reading relationship varies according to the nature of the RAN task and the particular aspect of reading ability under consideration in a sample of mixed-ability readers from grades 2 to 4. In addressing this aim, three research questions were posed. First, would the RAN-reading association differ according to the type of stimuli named in the RAN task? Second, would the RAN-reading association differ according to the direction of scanning required in the RAN task? Third, would the RAN-reading association differ according to the reading measures used? Further in regard to the first two questions, we were particularly interested in whether all reading measures would show a similar pattern of results.

Alphanumeric versus non-alphanumeric stimuli in RAN

With respect to the first research question, our findings show that for children in this age group alphanumeric RAN is strongly related to reading after controlling for variation in age, LK and PA, whereas non-alphanumeric RAN is not. This differential pattern is evident on measures of single, exception-word reading; orthographic choice; word and nonword fluency; and passage-reading rate, both oral and silent. These results are consistent with earlier studies, showing that beyond kindergarten non-alphanumeric stimuli are less useful predictors of reading ability; that is, once children begin to learn to read, it is alphanumeric RAN that remains a strong predictor of current and/or future reading abilities (Clarke et al., 2005; Misra et al., 2004).

Not all previous research conforms to this pattern however. Papadopoulos et al. (2016) reported that non-alphanumeric RAN predicted oral reading fluency as well as alphanumeric RAN in a sample of Greek-speaking children who were assessed in grades 1 and 2 (at 6;6 and 7;5). In addition, Kruk et al. (2014) tracked the progress of a sample of Canadian children from grade 1 to grade 3 and reported that non-alphanumeric RAN (assessed in grade 1) accounted for significant unique variance in exception word reading in grade 2. It would appear likely that these studies produced a different pattern of results from those reported here because children in the current study were somewhat older than their participants (i.e., grades 2-4).

Finally, our results provide no strong support for the view that RAN for letters is more closely associated with reading than RAN for digits (Abu-Hamour et al., 2012; Neuhaus et al., 2001). Of 15 significant correlations between various measures of RAN and reading, 8 involved RAN for digits, and 7 involved RAN for letters. Given this similarity in findings for the different versions of RAN, it would seem sensible to use RAN for digits in an assessment battery because they are not part of the alphabetic system and may therefore provide a truer reflection of children's current or future reading capacity as performance will not be adversely affected by a negative attitude towards reading.

Direction of scanning and the RAN-reading association

Our second research question concerned whether the RAN-reading association would differ according to the direction of scanning required in the RAN task. In regard to this issue, the results show little effect of scanning direction (horizontal vs. vertical) on the RAN-reading link for measures of exception-word reading accuracy, orthographic choice, or passage reading rate. However, only RAN-H was significantly associated with word and nonword reading fluency on the TOWRE-2.

Because to our knowledge no previous studies investigated vertical RAN, comparisons with previous literature are necessarily limited. We cannot, for instance, draw direct comparisons to previous studies using serial versus discrete RAN (e.g., Bowers & Swanson, 1991; Georgiou et al., 2013; Logan et al., 2011) because all versions of our RAN tasks were serial in format. Nevertheless, our findings are consistent with those of Protopapas et al. (2013b), who found that the RAN-reading relationship was just as strong in RAN-backward as in the traditional left-to-right version, thus casting doubt on the view that RAN is related to reading because both tasks involve serial *left-to-right* scanning (e.g., Abu-Hamour et al., 2012; Logan et al., 2011; Norton & Wolf, 2012). This result disconfirmed our original hypothesis. A further unexpected result relates to our original prediction that RAN-V may be more closely associated with performance on the TOWRE-2 real word and nonword fluency measure than the other reading assessments, because participants must name items column-by-column in RAN-V, just as they do in TOWRE-2 (de Jong, 2011; Protopapas et al., 2013a). The current findings disconfirmed this hypothesis, showing instead that performance on the TOWRE-2 was significantly associated with RAN-H but not RAN-V. Although we have no explanation for this finding at present, it is worth noting that the RAN-V format contained 10 short columns, each with just 5 items for naming. A different pattern of results might be obtained if RAN-V formatting were more similar to the presentation of words and nonwords in TOWRE-2, which contains a smaller number of longer columns (i.e., 4 columns of 27 for words; and 3 columns of 22 for nonwords.

The RAN-reading association according to reading measure

Finally, as regards the third research question, the RAN-reading link varies markedly as a function of the reading measure used. Moderate-to-strong correlations are evident between RAN (of various types) and exception word reading (*r*s from .31 - .44), orthographic choice (*r*s from .30 - .38), and fluency (for word reading, nonword reading, and passage reading; *r*s from .22 - .55). By contrast, correlations with nonword reading accuracy, passage reading accuracy, and passage comprehension were generally small and non-significant (*r*s from .03 - .35).

This general pattern of results is consistent with findings from previous studies, which showed that different aspects of reading are associated to varying extents with RAN. In particular, an association between RAN and orthographic processing (reflected in exception word reading and/or orthographic choice) is well-documented (e.g., Clarke et al., 2005; Conrad & Levy, 2007; Manis et al., 2000), as is the link between RAN and reading fluency (e.g., Bowers, 1993; Papadopolous et al., 2016; Savage & Frederickson, 2005). Nevertheless, some apparent discrepancies are also evident; for example, Abu-Hamour et al. (2012) reported a stronger association between RAN and nonword reading than RAN and exception word reading. They suggested that this finding might be due to their use of a timed, rather than untimed, nonword reading measure. Our findings provide additional support for that interpretation in that RAN-H was significantly associated with timed nonword reading (on the TOWRE-2) in the current study (*r*s = .41 - .43), but not with an untimed measure (Coltheart & Leahy, 1996; *r*s = .14 - .23). A further discrepancy is evident between the current study and that of Papadopolous et al. (2016) who reported that RAN was associated with oral but not silent reading, when the latter was measured in a task requiring children to identify the word boundaries from within a continuous line of print. The very different nature of our silent reading task, which required participants to read passages of text for understanding, presumably contributed to this difference in results.

Finally, although some previous research has shown a significant association between RAN and passage reading comprehension (e.g., Neuhaus et al., 2001) or RAN and passage reading accuracy (e.g., Savage & Frederickson, 2005), the current study provides little supporting evidence. Just a single correlation (between comprehension of orally read passages and RAN-H for digits) reached significance in the current study after controlling for age, LK, and PA (see Table 5). It is possible that the difference between the current findings and those of Neuhaus et al. reflect our use of partial correlations (which controlled for variation in PA), and/or their more specific focus on different components of RAN: in particular, pause time, which showed a significant association with comprehension; and articulation time, which did not. The difference between our findings and those of Savage and Frederickson are possibly due to the nature of the participant samples: our children constituted a younger, mixed-ability group attending a single school, whereas their participants were older children, on average, recruited by means of a newspaper advertisement targeting children with dyslexia.

Implications for researchers

The current findings have several important implications for researchers investigating the RAN-reading link.

First, they confirm that the association between RAN and reading depends on the use of highly familiar stimuli for naming, as indicated by Norton and Wolf (2012). Thus, in the current study children's reading performance was significantly associated with alphanumeric RAN (for digits and letters) but not with non-alphanumeric RAN. Second, they demonstrate, in line with the DDH (Wolf & Bowers, 1999), that alphanumeric RAN accounts for unique variance in reading after controlling for variation in age, LK, and most importantly, PA.

Third, the RAN-reading link appears to have its basis at least partly in both tasks' shared reliance on orthographic processing. Hence, both RAN-H and RAN-V show a significant association with exception-word reading accuracy, which is assumed to rely on children's ability to establish strong lexical-orthographic representations in memory (the lexical route of the DRM), and performance in an orthographic choice task. These observed associations are consistent with the view that children who process individual printed letters too slowly might, as a result, experience difficulty in activating multiple letter sequences and establishing orthographic representations in lexical memory. The adverse consequences for reading would extend to a lack of speed and efficiency in recognising words in text (Bowers et al., 1994), as observed in the current study.

Fourth, in contrast with the view that articulation is necessary for there to be an association between RAN and reading (e.g., Georgiou et al., 2013; Papadopolous et al., 2016), the current findings illustrate that silent reading rate is also associated with RAN, at least in the context of a passage reading task with comprehension as the ultimate goal.

Implications for the classroom

The findings from this study also have important practical implications for classroom teachers. The RAN task is currently underutilised in Australian classrooms, despite its ease of administration, especially with students who are experiencing difficulties with reading or might not be at the level of reading passages yet. The current findings address this problem by providing a clear explanation, accessible to principals, classroom teachers, and learning support practitioners amongst others, of specific associations between alphanumeric RAN tasks and different measures of reading. Hence, they will help to increase awareness of the RAN task as an important indicator of reading development, and in doing so provide support for the view expressed previously in the literature, that in addition to PA, RAN could be an effective diagnostic assessment of children's current and/or future reading abilities (e.g., Katzir et al., 2006). Second, the current findings provide a clear indication of how to proceed if a RAN deficit is suspected: In particular, children exhibiting RAN deficits should be followed up with more specific assessments, giving priority to orthographic abilities and reading fluency *in the first instance*.

These implications for classroom practice are important because if assessments do not include all relevant aspects of reading, some difficulties may remain undetected. As a result, some children might not receive intervention at all. For others, misidentification of the nature of their reading difficulties might mean that reading outcomes show little improvement despite intervention (Meisinger et al., 2010).

Strengths, Limitations and future directions

A strength of the current study lies in the inclusion of a wide range of RAN stimuli (objects, colours, letters, digits) rather than just one or two to establish a correlation with reading; and the use of various reading measures encompassing all component skills, including: word recognition (via the lexical route of the DRM) as well as phonological decoding (the non-lexical route); fluency (for words, nonwords, and passages of text); silent as well as oral passage reading; and comprehension.

The study is not without limitations, however. First, while the homogenous nature of the participant sample (all being drawn from the same school) has advantages in ensuring homogeneity of the educational environment, it may also not be reflective of wider school populations. Future research should replicate the findings in a more diverse, and possibly larger, sample in terms of socio-economics and ethnicity. Second, the number of children omitted from the study due to nonverbal ability (NVIQ < 80) exceeded the expected average of 10%. In fact, for this sample, the rate was much higher at just over 20% (16 out of 74). It remains unclear as to why this participant sample exceeded the expected average, but is worth noting that the included participants' scores were as expected on average.

Conclusion

In summary, the current results confirm findings that stronger diagnostic value lies in the alphanumeric versions of RAN rather than non-alphanumeric versions once children begin to learn to read (e.g., Clarke et al., 2005; Savage & Frederickson, 2005; Wolf & Bowers, 1999). In addition, our study adds weight to previous research showing that alphanumeric RAN is an important correlate of reading independent of PA and LK, and as such, constitutes a valuable addition to a diagnostic assessment battery. In particular, RAN performance can provide information regarding exception-word reading accuracy, as well as word and passage reading rate, all of which are essential skills for fluent reading. In terms of whether RAN-letters or RAN-digits should be administered to children in this age group, our evidence shows that similar results are obtained using either measure; however, as digits are more independent of the reading process their use may be preferable. Finally, in terms of which RAN format to use (vertical or horizontal) our findings suggest that both have value in assessment practice; although RAN-H may detect problems with single-word and nonword fluency measures that would not be detected using RAN-V.

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CHAPTER THREE

ENHANCING CLASSROOM ASSESSMENT PRACTICES: INCLUDING RAN AS A CONCURRENT PREDICTOR OF READING IN GRADES 2 TO 4

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Paper prepared for submission

Statement of authorship. The first author Joanne Fitzgibbon was responsible for the conception of the project under the guidance of Professor Linda Cupples and Dr Caroline Law (primary and associate supervisors). Mrs Fitzgibbon took responsibility for all data collection, initial data analyses, writing of all first drafts, and co-writing of all subsequent and final drafts. As primary supervisor, Prof Cupples contributed to the oversight of all aspects of the research, provided instruction and guidance for final data analyses, and co-wrote final manuscripts. As associate supervisor, Dr Law contributed to the oversight of all aspects of the research and co-wrote final manuscripts.

Abstract

The importance of closely monitoring children’s development of reading and reading-related skills in order to shape any necessary adjustments to teaching cannot be overstated. This study investigated the utility of a Rapid Automatised Naming (RAN) task for this purpose. Participants were 58 Australian children from grades 2-4. Standardised and non-standardised assessments were administered to measure a wide range of variables associated with successful early reading. Children were allocated to groups depending on their performance on RAN (digits) and PA measures in accordance with the Double Deficit Hypothesis. Children with below average RAN were significantly less accurate in their oral reading of exception words; fluency of both single-word and nonword reading; and, in all aspects of passage reading (accuracy, rate, and comprehension). Results indicate that without assessing for rapid naming a child’s profile of strengths and weaknesses may fail to indicate either the presence of a reading difficulty or its nature.

Introduction

The ability to read proficiently is essential for academic and professional success. The development of proficient reading relies on learning that takes place during the early-to-middle primary school years. During this period, children learning an alphabetic script acquire the ability to recognise letters and letter strings (written words) and to read them aloud accurately, both in isolation and in context. They also develop the ability to read aloud with increasing speed and expression; to read silently; and to understand what they have read (National Institute of Child Health and Human Development [NICHD], 2000). Furthermore, it is the attainment of these processes working to the point of automaticity (LaBerge & Samuels, 1974) that is vital for proficient, fluent reading and successful comprehension of text.

If children experience difficulty in any of these aspects of reading development, timely and targeted intervention is essential; that is, intervention based on a clear understanding of exactly which aspects are underdeveloped in a given reader. Hence, children's reading development should be closely monitored by ongoing assessment in order to shape any necessary adjustments to teaching and to implement appropriate intervention strategies as required (Meisinger, Bloom & Hynd, 2010; Norton & Wolf, 2012; Ozernov-Palchik et al., 2016). The important question that arises is how to decide on appropriate assessment strategies; that is, knowing which aspects to assess and which measures will provide the most useful information on which to base plans for differentiated instruction and targeted intervention. This knowledge is critical for both classroom teachers and learning support practitioners because failure to administer appropriate measures to assess reading and related skills in a timely manner could result in misdiagnosis and/or mistreatment of developing readers (Meisinger et al., 2010).

Over the last two decades, there have been substantial inquiries both nationally and internationally to increase awareness in teachers and the wider community as to which methods are most effective when it comes to the assessment, teaching, and remediation of reading. In the US, the *National Reading Panel* (NICHD, 2000), in Australia, the *National Inquiry into the Teaching of Literacy* (NITL; Department of Education Science and Training, [DEST], 2005), and in the UK, the *Independent Review of the Teaching of Early Reading in the United Kingdom* (Rose, 2006) extensively reviewed the vast amount of literature available on this topic. Common amongst their recommendations was the need for all aspects of teaching to be grounded in rigorous research. That said, the nature of the teaching profession does not always allow the time necessary to evaluate the evidence provided by various studies, in terms of how to best assess and teach reading; yet quality best-practice teaching, and assessment is crucial for children's successful reading acquisition (Foorman & Moats, 2004), and for the progress of students in mainstream classrooms in general (Grima-Farrell, Bain & McDonagh, 2011). The aim of this study was to provide teachers with behavioural evidence on the utility of the Rapid Automatised Naming (RAN) task (which involves the speeded naming of alphanumeric or other visual stimuli; e.g., colour patches, object drawings) to identify students for targeted reading intervention.

Types of targeted reading intervention

Phonics instruction

According to a dual route model (DRM) of single-word oral reading (e.g., Coltheart, Rastle, Perry, Langdon & Ziegler, 2001), skilled readers use two cognitive processing mechanisms for converting print to speech: a non-lexical, phonological decoding process, which involves the application of letter-sound rules; and a more efficient lexical process, which involves recognising a word's orthography and retrieving its associated phonological representation from memory. If children struggle to develop either of these mechanisms, reading difficulties can ensue (e.g., Castles & Coltheart, 1993). If children have decoding problems (reflected most clearly in difficulties reading unfamiliar or nonwords), phonics instruction, including phonological awareness (PA) and alphabet knowledge (letter sounds), can be used to intervene effectively**.** Evidence supports the importance of explicit, systematic training in the alphabetic principle; that is knowledge of how printed letters (graphemes) map onto spoken sounds (phonemes) as a key component to successful reading (Duff & Clarke, 2011; Ehri, Nunes, Stahl & Willows, 2001; Vellutino, Fletcher, Snowling & Scanlon, 2004; Wagner et al., 1997). By using common standardised measures of nonword reading, decoding problems are easy to identify, as are impairments in PA and letter-sound knowledge (Melby-Lervag, Lyster & Hulme, 2012). It follows that children with decoding difficulties should be provided with interventions targeting these skills.

More relevant to this study, however, mere lack of phonological decoding problems does not guarantee proficient reading: Students can be *accurate* single-word and text readers and still not read *fluently*; that is, "rapidly, smoothly, effortlessly and automatically with little conscious attention to the mechanics of reading such as decoding" (Meyer & Felton, 1999, p. 284). In the context of the DRM, skilled readers, who are both accurate and fluent, are highly proficient in their ability to read lexically (i.e., via a process of orthographic recognition). Like difficulties with phonological decoding, problems with reading *fluency* can emerge during the early-to-middle primary school years, becoming more apparent once accurate oral reading of single-words has been mastered. Correct identification and well-planned targeted intervention is equally important for readers who struggle with fluency as it is for readers who struggle with decoding accuracy. A popular intervention used to improve children's reading fluency is Repeated Reading (RR; National Reading Panel, 2000; Samuels, 1979).

Repeated Reading (RR)

Whilst RR can be implemented in a variety of ways, commonly it is an approach to instruction and intervention that involves students re-reading a suitable passage of text several times until a previously determined fluency criterion is reached (this criterion is usually measured in words per minute). Once the desired rate is achieved, the student reads another passage at the same level of difficulty several times until the criterion rate is achieved again. In some instances, the child is provided with feedback on oral reading errors, as well as number of words correct, and the results are graphed. When provided, feedback on oral reading errors is typically given after the child finishes reading the passage. On these occasions, errors are discussed and relevant sections of the passage may be read again, and/or decoding activities provided to assist with correct reading on subsequent occasions.

The National Reading Panel (2000) highlighted the effectiveness of RR as an intervention suitable for students with specific reading deficits in fluency; in particular, research suggested that RR might improve automaticity in reading and result in subsequent improvements in text comprehension (Faulkner & Levy, 1999; Kuhn & Stahl, 2003; Rasinski, 2006; Strickland, Boon & Spencer, 2013; Therrien, 2004). Therefore, RR would seem most appropriate for children who read slowly but with high levels of oral reading accuracy. Furthermore, although RR is recommended for children who display deficits in passage-reading fluency, it may also be an appropriate strategy for enhancing single-word reading efficiency. In sum, RR may lead to improvements in reading rate for single words and passages, as well as text reading comprehension in dysfluent readers.

How do teachers decide whether RR is appropriate for a given student?

As mentioned earlier, standardised assessments are available to evaluate children's word decoding ability and the precursor skills of PA and alphabet knowledge, thus facilitating decisions regarding the applicability of phonics instruction. The question addressed here is how teachers might decide whether RR would be an appropriate instructional strategy for a given student or group of students. Several measures are already used in the classroom to assess fluency, most commonly running records (Clay, 1993), and calculations of reading speed in words per minute (wpm; Hasbrouck & Tindal, 1992). However, these measures typically require students to read connected text (sentences and/or passages), and therefore cannot be used with early readers to identify those who may experience fluency difficulties down the track. The question is: How can teachers assess fluency in young children whose reading might not extend to passages of text, but be restricted primarily to single-words? In this study, we investigated use of the RAN task for this purpose. Our primary research question was whether the RAN task could be used as a simple screening tool to identify children in the early stages of reading development who would benefit from fluency training in the form of RR.

A persuasive argument can be made for the benefits of the RAN task in this context. It is simple to administer and does not require a teacher to make any qualitative judgements regarding a child's reading "fluency," as reflected for example in intonation. It takes a short time to complete, and provides opportunities to identify children at risk early on (i.e., even before reading instruction begins; e.g., Georgiou, Parrila, Manolitsis & Kirby, 2011; Lervag & Hulme, 2009). Other advantages are that RAN has been shown to predict reading proficiency independently of PA (Bowers, 1993; Norton & Wolf, 2012); and can be assessed independently of word or passage reading ability.

RAN and reading disability subtypes

As mentioned earlier, RAN is the ability to name quickly and accurately a set of visually presented, highly familiar symbols (colours, objects, digits, or letters) displayed in random order (Denckla & Rudel, 1974). Past literature suggested that poor performance on measures of RAN is a potential indicator of reading difficulties in children (Bowers & Swanson, 1991; Denckla & Rudel, 1976; Georgiou et al., 2011; Norton & Wolf, 2012).

A three-year longitudinal study by Lervag & Hulme (2009) found that RAN (for objects and colours) measured prior to reading instruction predicted later text reading fluency abilities, independently of PA and letter-knowledge. Additionally, their study found that once children began to learn to read, alphanumeric RAN (letter and digits) continued to predict text reading fluency. PA and RAN were acknowledged as being independent predictors of reading, suggesting that selective deficits would occur.

One consequence of identifying children with selective deficits is the formation of subtypes with particular profiles of processing strengths and weaknesses. With respect to RAN and PA, Wolf and Bowers (1999) proposed the "double deficit" hypothesis (DDH), which was later extended by other researchers (e.g., Compton, DeFries & Olson, 2001; Cronin, 2013; Katzir, Kim, Wolf, Morris, Lovett, 2008; Meisinger et al., 2010; Ozernov-Palchik et al., 2016). According to the DDH, PA and RAN are independent predictors of reading ability. Thus, readers can have selective deficits in PA or RAN, or a double deficit in both, with this latter subtype identified as the most impaired of all children in terms of reading fluency (Wolf, Bowers, Biddle, 2000).

Recent research by Ozernov-Palchik et al. (2016) produced results consistent with the DDH. They conducted a two-year study of 1215 preschool and kinder children using measures of RAN, PA, letter-knowledge and verbal short-term memory to profile children in kinder and allocate them to six specific subtypes in terms of pre-reading abilities: *average performers, below average performers, high performers, PA risk, RAN risk* and *double deficit risk*. Importantly stability of profile membership from preschool to kinder was established, as was the association between profile membership and subsequent (end of 1st grade) reading ability in a subset of 95 children.

Whilst Ozernov-Palchik et al. (2016) followed participants to the end of grade 1, Cronin (2013) tracked a participant sample of 130 kinder children through to grade 5, when 84 children remained. Measures of PA and RAN were used to profile children and allocate them to four subtypes in accordance with the DDH, in particular: no deficit; phonological (or PA) deficit; naming speed (or RAN) deficit; and double deficit (both PA and RAN). Cronin found that growth trajectories in oral reading of words and nonwords differed across the four groups: Children with no deficit in PA or RAN had significantly better growth trajectories than all other groups; children with a double deficit had significantly worse growth trajectories than all other groups; and the two groups of children with selective impairments (in either PA or RAN) did not differ from one another. Emphasising the importance of examining multiple reading outcome measures, the pattern of results was different for passage comprehension. In this case, only two significant differences were found: Children with a double deficit had worse growth trajectories than either children with no PA or RAN deficit or children with a PA deficit.

On the presumption that effective reading instruction or intervention should, in the first instance, focus on areas of weakness, the practical implication of findings that align with the DDH is that children with a selective deficit in RAN would not benefit from intervention targeting PA alone; and that children with a combined PA and RAN deficit would show only partial benefits from PA intervention. Based on this logic, there is a clear need for readers to be accurately profiled using appropriate assessment procedures. The importance of not only assessing children’s word-reading accuracy but also their reading rate in order to enable a thorough characterisation of their reading capabilities and difficulties, is demonstrated in a study by Meisinger et al. (2010). They suggested that the omission of fluency measures from reading assessments would lead to under identification of reading difficulties in some children, in particular those with a selective RAN deficit. Whereas single-word reading measures help to detect children who struggle with decoding (accuracy); fluency measures enable teachers and other practitioners to identify children who have (or might develop) passage-reading difficulties even though they may have mastered single-word decoding. Hence, Meisinger et al. explored the diagnostic value of including reading fluency measures in an assessment battery designed to identify children with reading deficits. The participants included 50 English-speaking children, ages 8 to 12 years, who had either, been referred to a university-based clinic previously because of reading difficulties, or already had a formal diagnosis of dyslexia. Children underwent a battery of assessments including IQ, single-word oral reading, passage comprehension, passage-reading fluency (measured in terms of accuracy and speed), RAN (for letters and digits), and PA.

Meisinger et al. (2010) identified three groups of readers. *Normal readers* displayed average comprehension; *Globally Impaired readers* displayed below average comprehension along with PA and RAN deficits (notably the most impaired group, which is consistent with the DDH); and *Reading Fluency Deficit readers* who displayed low average comprehension and deficits in RAN but not PA, which suggested RAN as a possible predictor of text comprehension. According to the researchers, had their assessment schedule included only single-word reading as a measure of ability, this third group of (dysfluent) readers, would not have been identified, thus resulting in under-identification of students with reading difficulties. On the other hand, students with single-word oral reading difficulties would have been identified using their fluency measure. Meisinger et al. concluded, therefore, that fluency measures were more sensitive for detecting reading problems than word reading accuracy measures. In response, it is important to note that reading accuracy measures are still needed in order to identify whether poor fluency might result from decoding problems or something else (e.g., lack of automaticity). Finally, with respect to the use of RAN as an indicator of reading fluency, the findings reported by Meisinger et al. suggested that RAN measures for letters and digits were closely associated with rate of reading of connected text in their sample of school-aged children with reading difficulties. As they noted, however, it remains to be seen whether the findings would be replicated in a typical school sample using multiple measures of fluency to ensure that results do not reflect the use of particular assessments. These suggestions were incorporated into the current study.

To summarise, the studies reviewed here indicate that assessment inclusive of both PA and RAN allowed for subtyping of readers, which could aid in the design of targeted intervention; for example, those exhibiting deficits in RAN should benefit from interventions that explicitly train automaticity (e.g., RR); those with single PA deficits should benefit from explicit, systematic training in PA; and those with a double-deficit should benefit most from a combination of instruction in PA and RR.

The current study

The importance of timely, research-based assessment procedures to inform strategies for classroom reading instruction and to plan for targeted intervention has been well established (Foorman & Moats, 2004; Kuhn, Schwanenflugel, & Meisinger, 2010; NICHD, 2000). If inappropriate or insufficient measures are included in an assessment battery, it follows that a child's profile of strengths and weaknesses may fail to indicate either the presence of a reading difficulty or its nature (e.g., with respect to decoding or fluency). Furthermore, such misidentification might lead to an inappropriate choice of instructional strategy, which in turn could be associated with an absence of improved reading outcomes following intervention. Previously, this misidentified subgroup of readers might have been classified as "treatment resisters" (Torgesen, Wagner, Rashotte 1994), but the lack of correct identification of the nature of their reading deficit, and therefore inappropriate intervention, may have been responsible. Wolf et al. (2000) suggested that many such "resisters" were those with a single core deficit in RAN or a double-deficit in both PA and RAN.

The current study addressed this issue of appropriate assessment, with especial focus on investigating the utility of the RAN task for identifying children most likely to benefit from targeted intervention for reading fluency (namely, RR). The importance of fluent reading has been discussed previously, and here we reiterate that the definition used in this study is based on that of Meyer & Felton (1999) who defined it as reading "rapidly, smoothly, effortlessly and automatically with little conscious attention to the mechanics of reading such as decoding" (p. 284). Whilst it is acknowledged that some definitions also include syntax and expressiveness as elements of fluent reading (Kuhn & Stahl, 2003), evidence suggests that both are difficult to measure objectively, and moreover that both contribute minimally to comprehension; rather it is accurate and fast word and text reading that enables expressive reading to emerge (Miller & Schwanenflugel, 2006).

To extend results reported previously for children with diagnosed or suspected reading difficulties (Meisinger et al., 2010), the current participant sample was drawn from a non-clinical population; that is, students within a school setting who had no diagnosed reading disabilities. Furthermore, since fluency deficits become more apparent once accurate reading of single-words has been mastered, and curriculum demands require students to extract information from connected text (Therrien, Kirk & Woods-Groves, 2012), the focus of this study was on children in the middle primary-school grades (grades 2 to 4). Inclusion of children in this age range differentiated this research from some other recent studies targeting younger children (e.g., Olzernov-Palchik et al., 2016), and also enabled us to investigate a range of word and passage reading skills that would not have been feasible in a group of younger, less skilled children.

A variety of reading measures was included in light of previous research suggesting that, although alphanumeric RAN predicts reading disability in both children and adults (Wolf et al., 2000), it is more strongly associated with word reading efficiency and passage reading fluency than with decoding tasks and nonword reading measures, which in turn are more closely linked to variation in PA. For example, a three-year study by Bowers (1993) found that measures of PA were related to word reading accuracy, whereas performance on a RAN-digit subtest related more precisely to reading rate in a sample of average and poor readers from grades 2 to 4. Savage and Frederickson (2005) also demonstrated a link between RAN for digits on the one hand and reading rate and accuracy on the other; whereas PA predicted accuracy and comprehension.

Reading measures used in the current study included both passages and single-words. Two passage reading tasks were included. In one, passages were read aloud and performance was evaluated in terms of oral reading accuracy, rate, and comprehension. In the second task, passages were read silently, with performance evaluated in terms of reading rate and comprehension. Single-word reading was assessed in terms of accuracy and rate using real words, both regular (pronounced in line with common letter sound associations, such as "context") and exception (with pronunciations that violate common letter sound associations, such as "meringue"), as well as nonwords. Findings obtained on exception words and nonwords were of particular relevance. Exception word reading assesses the integrity of the DRM's lexical mechanism (because such words cannot be read correctly using letter-sound rules), whereas nonword reading assesses the non-lexical mechanism. Furthermore, as noted earlier, the integrity of the lexical reading mechanism is crucially important for skilled (accurate and fluent) reading. As such, we might expect to find a stronger association between RAN (as a measure of fluency) and reading accuracy for exception words compared to nonwords. Consistent with this suggestion, Clarke, Hulme and Snowling (2005) found that RAN for digits accounted for unique variance in the reading of exception words in a group of thirty children, ages 8 to 11 years.

Research questions and hypotheses

In light of this background, the current study investigated the potential benefits of including the RAN task in a battery of assessments designed to profile readers in a manner that would assist in identifying appropriate instruction or intervention strategies. More specifically groups of children with good versus poor RAN were identified from within an unselected middle-primary school sample and were then compared on a range of reading measures. Importantly, although the groups differed in RAN, they were matched on PA, because this is a measure that consistently discriminates good from poor readers. More specifically, half of the children in each RAN group had average or above average PA scores on a standardised test, whereas the other half had below average PA. The inclusion of children who differed systematically on these two variables enabled us to address three research questions (RQs).

1. Would children who differed in RAN ability but were matched on PA perform differently across a range of single-word reading measures, including: oral reading accuracy of exception words and nonwords, orthographic recognition, and reading fluency (speed and accuracy) for real words and nonwords?

2. Would children who differed in RAN ability but were matched on PA perform differently across a range of passage-level reading measures, including accuracy (of oral reading), rate, and comprehension?

3. Would the reading deficits associated with poor RAN differ from those associated with poor PA?

Based on the literature regarding subtype comparisons, we predicted that children differing in RAN ability but matched on PA would perform differently across a range of single-word (RQ1) and passage reading (RQ2) measures. More specifically, children with good RAN were expected to perform relatively better on measures of orthographic recognition (e.g., exception word reading), single-word reading fluency, and passage-reading rate; whereas children with poor RAN were expected to struggle on tasks assessing reading speed and efficiency (for both real words and passages). In regard to RQ3, we predicted that children with a RAN deficit would exhibit different reading weaknesses than children with a PA deficit, and in particular that children with a selective RAN deficit (i.e., in the presence of good PA), would perform relatively better than children with a selective PA deficit in reading accuracy, especially for nonwords.

Method

Participants

A total of 74 monolingual English-speaking Australian students from Grades 2, 3 and 4 within the same independent school sector took part in the study, which was part of a larger investigation into children's reading fluency. Sixteen students were later omitted from the data analysis, one who left the school during the data collection phase, and 15 who failed to meet the inclusion criteria of a nonverbal IQ > 80. As a result, data reported here were collected from 58 included students, 32 males and 26 females. The sample included 11 children from grade 2 (Mean age = 7 years; 6 months), 30 from grade 3 (Mean age = 8 years; 6 months), and 17 from grade 4 (Mean age = 9 years; 6 months). The participants met the following additional inclusion criteria of: (1) no known history of learning difficulties; (2) normal hearing; (3) normal or corrected-to-normal vision; and (4) English as the home language (although one child also spoke a second language at home). Students were not excluded from the study on the basis of a previous diagnosis of attention deficit/hyperactivity disorder (ADHD). A total of 9 participants out of 58 had been referred to a speech pathologist and/or received intervention for learning difficulties at school.

The school is located within a medium socio-economic area. The participants' caregivers provided informed consent; and relevant background information was collected in the form of a parental survey concerning participants' age; caregivers' level of education; languages spoken at home; previous referral to a speech pathologist; and intervention received at school for learning difficulties (either participant or family members). Caregivers were, in general, well-educated, with all but 3 having 13+ years of education. Parents/siblings of 16 participants reported receiving intervention for learning difficulties at school. When asked to describe at-home reading practices most caregivers reported participating in some reading activities with their child, be that school-related or for leisure, several times a week. In exchange for their participation, caregivers received a report of their child's results.

Measures

A battery of standardised and non-standardised assessments was used to measure a wide range of variables associated with successful early reading. All assessment sessions were audio recorded for later transcription, scoring, validity, and reliability purposes. Participants' reading outcomes were profiled using measures of: oral reading accuracy (of regular and exception words, and nonwords); orthographic recognition (lexical decision); real word and nonword reading fluency (speed and accuracy); and passage-reading accuracy, rate, and comprehension measures. Subtyping variables used to allocate readers to groups in accordance with the DDH were: RAN (for digits) and PA (a combination of elision, blending words and phoneme isolation tasks). Control variables included in the study were: non-verbal cognitive ability, receptive vocabulary, alphabet knowledge, phonological short-term memory, and syntactic ability.

Reading outcome measures

Word reading accuracy.

The Coltheart and Leahy Reading Test (1996) was administered to assess oral reading accuracy of single-words (regular and exception) and nonwords. The test contains 30 items of each word type, making a total of 90 items altogether. All words and nonwords were printed on cards and presented to participants individually. As no time limit is applied in this test, a child's raw score is computed simply as the number of words or nonwords read correctly (out of 30). These raw scores were used for descriptive and analysis purposes.

A second measure of word reading accuracy, the Orthographic Choice Task (Olson, Wise, Conners, Rack & Fulker, 1989) was included to assess participants' knowledge of orthography. Participants were provided with 52 word/nonword pairs (e.g., bark / barc) and asked to select (point to) the real word from each pair. Since both items within a pair have the same pronunciation when decoded using letter-sound rules, students must use their knowledge of word-specific orthography to respond correctly. Children's raw scores (calculated as the number of correctly selected real words out of 52) were used for descriptive and analysis purposes.

Word and nonword reading fluency.

The Test of Word Reading Efficiency – Second edition (TOWRE-2; Torgesen, Wagner & Rashotte, 2012), was used to measure oral reading fluency for single-words and nonwords. This measure is comprised of two subtests: the sight word efficiency test (SWE) and the phonemic decoding efficiency test (PDE). SWE measures a reader's ability to read real words efficiently; that is to recognise them as whole words (orthographic processing) and to pronounce them accurately and quickly. Phonemic decoding assesses graphophonic abilities in readers by asking them to decode unfamiliar letter strings (nonwords) efficiently, with accuracy and speed. Participants read vertically as many real words or nonwords as possible in a 45-second period, aiming for both accuracy and speed. Two practice lists of eight words and eight nonwords were completed prior to the test proper. Children's scores were computed as the number of words or nonwords read correctly within the allocated (45-second) time period, providing a raw score from which a standard score was calculated. When combined, these two subtests provide a Total Word Reading Efficiency (TWRE) score. Standard scores (distributed with a mean of 100 and standard deviation of 15) were used here for descriptive and analysis purposes.

Passage Reading - accuracy, rate and comprehension.

The Neale Analysis of Reading Ability – Third Edition (NARA-3; Neale, 1999) was administered as per instructions in the test manual to assess participants' reading accuracy, speed, and comprehension at the passage level. Students were timed as they read the passages aloud, but no time limit was imposed. The standard version, Form 1, contains six passages of increasing difficulty. Students progress through each passage until 16 oral reading errors are made in a single passage (accuracy score based on number of words read correctly). Raw scores and percentile ranks, were calculated according to instructions in the test manual.

A second non-standard version of the NARA-3 was devised and administered using additional matched passages available in the test package. In this non-standard measure students were timed as they read each passage *silently*, with no time limit imposed. Raw scores were computed for words per minute read and number of correct answers to comprehension questions. Testing was stopped once the participant made more than three errors on the comprehension questions for a given passage.

Subtyping measures

***RAN*.**

Participants' rapid naming skills were assessed using the RAN/RAS: Rapid Automatised Naming and Rapid Alternating Stimulus Tests *(*RAN/RAS; Wolf & Denckla, 2005). The original RAN task of Denckla and Rudel (1976) comprises four subtests: object naming, colour naming, digit naming, and letter naming, each with 50 items arranged in 5 rows of 10. Participants are asked to name the randomly ordered stimuli on the page as quickly and accurately as possible from left to right and top to bottom. Prior to the test, 2 rows of 5 items are completed for practice. A raw score is obtained by recording the time in seconds to name all 50 items in the subtest. In the current study, raw scores were used to derive standard scores (distributed with a mean of 100 and standard deviation of 15), which were used for descriptive and analysis purposes. In the current research, results on the digit naming subtest were used to identify participant subtypes. The subtypes were then confirmed using data from letter naming, object naming, and colour naming.

PA.

PA was assessed using three core tests from the Comprehensive Test of Phonological Processing – Second edition (CTOPP-2; Wagner, Torgesen & Rashotte, 2013): Elision (EL), in which participants are asked to remove phonological units from words to make other words; Blending Words (BW), in which participants are asked to combine sounds to form words; and Phoneme Isolation (PI), in which participants isolate individual sounds within words. For all subtests participants' scores were calculated by adding the number of correct responses, providing a raw score from which standard scores (distributed with a mean of 100 and standard deviation of 15) were then computed. For all measures, testing was discontinued after three consecutive incorrect responses.

Control Tasks

Five assessments were administered to control for variation in children's non-verbal IQ, alphabet knowledge, receptive vocabulary, syntactic understanding, and phonological short-term memory, all of which might influence their performance on the reading and reading-related tasks of primary interest. Non-verbal IQ scores were also used for inclusion purposes; that is, only participants with IQs > 80 were included in study.

Alphabet knowledge.

Alphabet knowledge was assessed using the NARA-3 (Neale, 1999). The 26 letters of the English alphabet were presented in lower case and participants were asked to say the sound each letter makes. Raw scores were computed by tallying the number of correct sounds produced (out of 26). As this is not a standardised test raw scores were used for descriptive and analysis purposes.

Receptive vocabulary.

The Peabody Picture Vocabulary Test - Fourth Edition (PPVT-4; Dunn & Dunn, 2007) was used to obtain a measure of children’s receptive vocabulary. On each trial, children are presented with a set of pictures, four to a page. The examiner utters a word that describes one of the pictures, wherein the examinee is asked to point to the picture that best represents the spoken word. In the current study, raw scores (number of correctly identified pictures) were used to obtain standard scores, distributed with a mean of 100 and standard deviation of 15, which were used for descriptive and analysis purposes.

Syntactic understanding.

Participants’ ability to understand spoken sentences was assessed using the syntactic understanding (SU) subtest from the Test of Language Development 4 (TOLD-4; Newcomer & Hammill, 2008). Participants were asked to choose from 3 pictures the one that matched most closely the spoken sentence provided. Testing was discontinued after five consecutive incorrect responses. Raw scores were calculated by tallying the number of correct responses out of a possible thirty. Although standard scores can be calculated for participants from ages 4.0 through to 8.11, only raw scores were computed for current purposes as many participants were beyond this age range.

Phonological memory.

The *Memory for Digits (MD)* subtest from the CTOPP-2 (Wagner et al., 2013) was used to assess participants' phonological short-term memory. In this subtest, children are required to repeat verbatim orally presented number sequences that gradually increase in length. Testing is discontinued after three consecutive incorrect responses. Raw scores were obtained by adding the number of correct responses out of a possible 28, from which standard scores were derived (distributed with a mean of 10 and standard deviation of 3). Standard scores were used in the current study for description and analysis.

Non-verbal Cognitive ability.

Nonverbal cognitive ability was assessed using the 2-subtest form of the Wechsler Non-verbal Scale of Ability (WNV; Wechsler & Naglieri, 2006), which was administered according to instructions in the test manual. All participants completed the matrices subtest in which they were asked to select one option from a range of pattern pieces to correctly complete an incomplete grid. Participants also completed one other sub–test, the nature of which depended on their age: Children up to 7;11 (years; months) completed the recognition subtest, whereas children aged 8;0 and above completed spatial span. Full scale scores (distributed with a mean of 100 and standard deviation of 15) were computed for descriptive and analysis purposes.

General Procedure

Ethical approval for the research was granted by the Macquarie University Human Research Ethics Committee, and written permission was obtained from all parents and carers prior to testing. All participants were assessed individually during school hours in a well-ventilated and well-lit room located at the students' school. This setting was chosen because it was familiar to the students. Testing was divided into two sessions of approximately 60 minutes each with the order of measures being fixed so as not to confound results. Due to the length of each session certain procedures were incorporated to support children's optimal performance.

- Breaks were incorporated between each assessment task as required.
- Activities were used to transition between assessments, including some simple physical activities (e.g., stretching, hand and finger exercises, star jumps, etc.).
- Students were permitted to have a water bottle with them at all times.
- Students' verbal assent was obtained prior to each assessment task, and they were assured at regular intervals during testing that they could defer testing or withdraw from the study at any time by requesting to do so or asking to return to their classroom.

Prior to conducting individual testing, the first author (who was the sole examiner) visited children's classrooms to introduce herself to students and, together with the classroom teacher, provided an explanation about what students could expect to happen during the study.

Statistical analysis

Data analysis was conducted in two steps. The first step was to assign participants to subtypes according to their RAN and PA abilities. Included subtypes were:

- No deficit (No-D) readers (with average or above average PA and RAN);
- PA deficit (PA-D) readers (with below average PA and average or above average RAN);
- RAN deficit (RAN-D) readers (with below average RAN and average or above average PA); and
- Double deficit (DD) readers (with below average PA and RAN).

To ensure a minimum separation of 5 standard score points between children allocated to above and below average groups, those with a standard score of between 96 and 99 (inclusive) on either task were not included for subtyping. A further child, who scored nearly 2 SDs below the mean on receptive vocabulary (PPVT-4 standard score = 73) and indicated that he knew no letter sounds at all was also omitted. A total of 44 children remained in the subtyping sample. A series of two-way analyses of variance (ANOVAs) with non-repeated measures on RAN (average vs. below average) and PA (average vs. below average) was conducted to compare the resulting participant subtypes on RAN, PA and the various control variables. Given the large number of analyses conducted, a conservative type I error rate of .01 was adopted.

The second step in data analysis was to examine how children allocated to the 4 participant subtypes performed on the range of reading outcome measures. Once again, a series of two-way ANOVAs, with non-repeated measures on RAN and PA, was conducted; and given the large number of analyses, a conservative type I error rate of .01 was adopted.

Table 1. Mean scores (with standard deviations and ranges) on RAN, PA and control measures according to participant subtype (*N* = 44)

	n	Measure	Age	RAN[a]				PA[a]	NVIQ[a]	Vocab[a]	LSK[b]	STM[c]	Syntax[d]
				Digits	Letters	Objects	Colours						
Subtype													
DD	11	*Mean*	9.05	84.4	85.9	85.3	82.4	83.8	98.2	108.4	24.1	9.7	25.8
		SD	(0.87)	(7.66)	(12.89)	(8.44)	(13.03)	(9.34)	(6.01)	(9.12)	(2.02)	(2.65)	(1.17)
		Range	8-11	76-94	55-105	73-102	55-101	69-94	88-107	95-121	20-26	7-14	24-28
PA-D	14	*Mean*	8.42	105.6	103.1	99.4	100.5	86.7	97.4	104.4	23.1	9.0	25.6
		SD	(0.75)	(5.49)	(9.30)	(9.21)	(11.47)	(6.32)	(8.54)	(11.75)	(2.66)	(2.22)	(2.85)
		Range	7-10	100-114	89-118	77-120	80-119	75-94	86-115	86-135	19-26	6-14	19-30
RAN-D	7	*Mean*	8.26	87.4	87.4	86.3	81.4	105.6	97.9	107.1	25.7	10.7	25.6
		SD	(1.02)	(4.39)	(5.03)	(9.18)	(9.14)	(3.74)	(11.48)	(11.73)	(0.49)	(4.39)	(2.76)
		Range	7-10	81-95	79-92	72-98	71-96	100-112	82-115	92-129	25-26	6-17	22-30
No-D	12	*Mean*	9.13	111.4	109.7	106.3	106.0	113.2	106.0	112.8	25.3	12.0	26.6
		SD	(0.81)	(7.43)	(13.03)	(11.32)	(15.77)	(11.36)	(13.38)	(8.75)	(1.22)	(3.57)	(1.68)

n	Measure	Age	RAN[a]				PA[a]	NVIQ[a]	Vocab[a]	LSK[b]	STM[c]	Syntax[d]
			Digits	Letters	Objects	Colours						
	Range	8-11	102-127	94-134	93-123	88-141	100-137	82-125	96-127	22-26	6-18	24-29
Variable		Significance levels for main and interaction effects from two-way ANOVAs										
RAN		$p = .642$	$p < .001$	$p < .001$	$p < .001$	$p < .001$	$p = .055$	$p = .251$	$p = .797$	$p = .249$	$p = .776$	$p = .582$
PA		$p = .868$	$p = .036$	$p = .246$	$p = .197$	$p = .573$	$p < .001$	$p = .193$	$p = .278$	$p = .004$	$p = .047$	$p = .582$
RAN*PA		$p = .006$	$p = .509$	$p = .468$	$p = .335$	$p = .428$	$p = .381$	$p = .161$	$p = .147$	$p = .691$	$p = .307$	$p = .367$

Note. Age = age in years; RAN = RAN/RAS Rapid Automatised Naming of digits, letters, objects, and colours; PA = CTOPP-2 Phonological Awareness Composite score (elision, blending, phoneme isolation); NVIQ = Wechsler Nonverbal standard score; Vocab = Peabody Picture Vocabulary Test – 4; LSK = letter-sound knowledge; STM = Phonological short-term memory; Syntax = TOLD 4 Receptive syntax; DD = double deficit in both RAN and PA; PA-D = selective deficit in PA with average or above average RAN; RAN-D = selective deficit in RAN with average or above average PA; No-D = No deficit in RAN or PA (average or above average in both).

[a]Standard scores with a mean of 100 and SD of 15

[b]Raw score (out of 26)

[c]Standard scores with a mean of 10 and SD of 3

[d]Raw score (out of 30)

Results

Subtyping

As noted above, a total of 44 participants qualified for inclusion in the subtyping sample. Table 1 contains a summary of these participants' scores on RAN, PA, and the different control variables according to participant subtype. These results show a clear and statistically significant separation between the groups in their RAN and PA profiles. On average, the DD group scored approximately 1 SD below the typical mean on both variables, the No-D group scored above average on both variables, and the PA-D and RAN-D groups showed selective impairments in PA and RAN respectively, with above average performance on the other variable. Despite these marked differences in RAN and PA, participants achieved similar levels of performance on the various control tasks, except for a significant difference in letter-sound knowledge which favoured children with good PA (p = .004, see Table 1).

RAN and single-word reading

Table 2 shows the mean number of exception words and nonwords read correctly according to participant subtype. The results for exception word reading provide evidence that children with average or above average RAN were more accurate in reading exception words than children with below average RAN ($F[1,40] = 10.30$, $p = .003$). On the other hand, there is little evidence of an advantage in exception word reading for children with higher levels of PA ($F[1,40] = 3.22$, p = .080) and no suggestion of an interaction ($F[1,40] = 1.64$, p = .208). A different pattern of results is seen for nonword reading, however, where the main effect of RAN was not significant ($F[1,40] = 3.30$, $p = .077$), but children with higher levels of PA scored better than children with lower levels ($F[1,40] = 16.45$, p < .001), regardless of variation in RAN (F < 1). The mean standard scores achieved by participants of each subtype on the TOWRE-2 tests of single-word and nonword reading fluency are also shown in Table

2. Children with higher RAN scores achieved better fluency results than children with lower RAN scores on both words ($F[1,40] = 13.84$, $p = .001$) and nonwords ($F[1,40] = 9.43$, $p = .004$). Similarly, children with higher levels of PA achieved better fluency results than children with lower levels of PA on both words ($F[1,40] = 9.28$, p = .004) and nonwords ($F[1,40] = 18.78$, p < 001). These results differ from those for single-word reading *accuracy*, where effects of RAN were limited to exception words and effects of PA were restricted to nonwords. They resemble the earlier findings, however, in not providing any evidence for an interaction between RAN and PA (both Fs < 1); which suggests that RAN is related to reading independently of PA and vice versa. The final single-word reading task included here was the Orthographic Choice Task, which revealed no significant effect of either RAN ($F[1,40] = 4.23$, $p = .046$) or PA ($F[1,40] = 3.35$, $p = .075$) and no significant interaction between them ($F[1,40] = 1.32$, $p = .258$; see Table 2).

Taking account of the various single-word reading results described here, it is apparent that, in accordance with hypothesis 1, children who differed in RAN ability, but were matched on PA, performed differently across a range of single-word reading measures, in particular, those that involved oral reading accuracy and/or fluency.

Table 2. Mean scores (with standard deviations) for word and passage reading measures according to participant subtype (*N* = 44)

		Single-Word Reading					Passage Reading				
		Accuracy[a]		Fluency[b]		Silent[c]	Oral reading[d]			Silent reading[d]	
	Measure	Exception	Nonword	SWE	PDE	Orth. choice	Accuracy	Rate	Comp[n]	Rate	Comp[n]
Subtype											
DD	Mean	16.2	15.8	85.4	82.1	36.0	38.5	60.5	14.4	129.0	9.5
	(SD)	(4.12)	(8.61)	(11.43)	(11.18)	(3.41)	(19.08)	(18.44)	(7.00)	(56.45)	(4.72)
PA-D	Mean	18.7	18.5	100.0	91.9	37.7	45.1	74.8	17.4	124.8	11.4
	(SD)	(3.22)	(6.94)	(14.10)	(15.26)	(5.14)	(12.81)	(18.01)	(5.57)	(74.73)	(2.68)
RAN-D	Mean	16.9	22.9	97.3	96.7	37.3	48.1	60.86	18.7	92.0	13.7
	(SD)	(7.29)	(4.38)	(14.06)	(10.56)	(9.20)	(19.73)	(22.36)	(9.21)	(51.56)	(5.85)
No-D	Mean	22.8	27.3	112.7	110.6	43.3	72.3	94.5	28.0	197.8	23.3
	(SD)	(2.80)	(2.67)	(12.16)	(10.22)	(6.75)	(20.30)	(22.00)	(7.29)	(83.74)	(9.72)
Variable		Significance levels for main and interaction effects from two-way ANOVAs									
RAN		$p = .003$	$p = .077$	$p = .001$	$p = .004$	$p = .046$	$p = .008$	$p < .001$	$p = .008$	$p = .026$	$p = .006$

PA	$p = .080$	$p < .001$	$p = .004$	$p < .001$	$p = .075$	$p = .002$	$p = .114$	$p = .001$	$p = .415$	$p < .001$
RAN*PA	$p = .208$	$p = .663$	$p = .927$	$p = .597$	$p = .258$	$p = .120$	$p = .129$	$p = .160$	$p = .016$	$p = .054$

Note. Exception = Coltheart and Leahy exception words; Nonword = Coltheart and Leahy nonwords; SWE = TOWRE-2 word fluency; PDE = TOWRE-2 nonword fluency; Orth. choice = Olson et al.'s orthographic choice task; Passage reading = NARA-3; DD = double deficit in both RAN and PA; PA-D = selective deficit in PA with average or above average RAN; RAN-D = selective deficit in RAN with average or above average PA; No-D = No deficit in RAN or PA (average or above average in both).

[a]Raw score (number read correctly out of 30)

[b]Standard scores with a mean of 100 and SD of 15

[c]Raw score (number correct out of 52)

[d]Accuracy = raw score (based on number of words read correctly); Rate = words per minute; Comp^{n} = raw score (number correctly answered comprehension questions)

RAN and passage reading

Table 2 shows the mean scores according to participant subtype for oral reading accuracy, oral and silent reading rate (in words per minute), and passage comprehension on the NARA-3. In general, these results show that participants with higher RAN scores were more accurate oral readers than those with lower RAN scores ($F[1,40] = 7.72$, $p = .008$). They read aloud more quickly ($F[1,40] = 14.87$, $p < .001$), and comprehended more of what they read both orally ($F[1,40] = 7.81$, $p = .008$) and silently ($F[1,40] = 8.49$, $p = .006$). The only passage-reading variable that did not reveal a significant effect of RAN ability was silent reading rate ($F[1,40] = 5.38$, $p = .026$). The pattern of results differed somewhat with respect to the effects of PA. Children with higher levels of PA were also more accurate in their oral reading of passages than children with lower levels of PA ($F[1,40] = 11.02$, p = .002), and they comprehended more of what they read both orally ($F[1,40] = 11.65$, $p = .001$) and silently ($F[1,40] = 17.01$, $p < .001$). Unlike children who differed in RAN, however, those who differed in PA did not show a corresponding difference in their rate of either silent ($F < 1$) or oral reading ($F\ [1,40] = 2.61$, p = .114). Finally, as with all previous analyses of reading outcome measures, the interaction between RAN and PA was not significant for any of the passage-reading measures (with *p* ranging from .016 to .129; see Table 2).

Taking account of the passage reading (accuracy, rate and comprehension) results described here, it is once again evident that children who differed in RAN ability, but were matched on PA, performed differently across a range of passage reading measures, in particular, those that involved oral reading accuracy, oral reading rate, and oral and silent reading comprehension.

Reading deficits associated with RAN versus PA

Our final research question was whether the reading deficits associated with poor RAN would differ from those associated with poor PA. Consistent with our hypothesis, the results indicate that children who differed in RAN ability showed a pattern of strengths and weaknesses that was different from the pattern shown by children who differed in PA. In terms of single-word reading, RAN was associated with exception word reading accuracy but not nonword reading, whereas PA was linked to nonword reading accuracy but not exception word reading. In terms of passage reading, RAN was linked to reading rate, whereas PA was not.

In summary, the results reported here indicate the value of including RAN in a screening battery designed to identify a child's profile of possible reading strengths and weaknesses. Thus, without assessing for RAN, screening test outcomes may fail to indicate either the presence of a reading difficulty or its nature; specifically, deficits in exception word reading and oral reading rate (single-words and passages of text) may remain unidentified.

Discussion

The primary aim of this study was to investigate the utility of the RAN task as a screener for identifying potential reading difficulties in children from grades 2 to 4 (ages 7 to 11). A particular focus was whether the RAN task would be useful for identifying those children who had poor reading fluency or were at risk of developing poor reading fluency. To address this aim, children were divided into reader subtypes according to their performance on a RAN digits task and a standardised measure of PA, which is widely acknowledged as an important pre-reading skill. Three research questions were addressed. First, would children who differed in RAN but were matched on PA perform differently across a range of single-word reading measures; second, would children who differed in RAN but were matched on

PA perform differently across a range of passage-level reading measures; and third, would the reading deficits associated with poor RAN differ from those associated with poor PA.

The results showed that children with below average RAN were significantly less accurate in their oral reading of exception words than children with average or above average RAN, despite their similar levels of PA. The RAN groups also differed significantly in their fluency of both single-word and nonword reading, and in all aspects of passage reading (accuracy, rate, and comprehension). Importantly, two of these significant differences in reading performance were not seen when children with below average PA were compared to children with average or above average PA. In particular, children who differed in PA showed no corresponding difference in exception word reading accuracy or passage reading rate. They did, however, differ in nonword reading accuracy, as expected. These results indicate that children with a RAN deficit exhibited a different profile of reading strengths and weaknesses than children with a PA deficit; thus confirming earlier studies in the literature (e.g., Cronin, 2013; Meisinger et al., 2010; Ozernov-Palchik et al., 2016).

What does RAN add to a screening battery?

Our results reinforce claims in the literature concerning the importance of administering appropriate screening assessments, to avoid either mis-diagnosis and/or mistreatment of developing readers (e.g., Meisinger et al., 2010). More specifically, the results of this research are consistent with findings from previous studies in demonstrating the utility of the RAN task for identifying fluency deficits in children in the early stages of reading development (e.g., Bowers & Swanson, 1991; Denckla & Rudel, 1976; Georgiou et al., 2011; Norton & Wolf, 2012).

In the current study, children with a selective RAN deficit make up approximately 12% (7 out of 58) of the included sample (i.e., children with NVIQs of 80 or above). Had the RAN task not been included along with PA for subtyping purposes, these children would have been misdiagnosed as being at no risk of reading difficulty. In fact, they would have been classified as good readers and included in a group along with the No-D subtype, thus adding considerable variability to that group's performance across the range of reading outcomes measure. Limiting the screening assessments to only PA would also have resulted in no distinction being made between DD children and those with a selective PA deficit (PA-D), yet these children differ from one another in their profile of reading strengths and weaknesses, as supported by the statistically significant differences between groups of children who differed in RAN, regardless of their PA.

RAN deficits in relation to reading strengths and weaknesses

The profile of reading strengths and weaknesses observed in the current study for children who differed in RAN but were matched on PA was consistent with expectations based on previous research. Thus, we found a stronger association between RAN and reading accuracy for exception words compared to nonwords, consistent with the findings of Clarke et al. (2005). The present study also supports earlier work by Bowers (1993), showing that performance on a RAN digit subtest was more closely related to text reading rate than reading accuracy in children from grades 2 to 4. Furthermore, our findings are consistent with those of Meisinger et al. (2010), who reported that RAN measures (for letters and digits) were closely associated with rate of reading of connected text in a sample of school-aged children with reading difficulties. In the current study, we replicated and extended their findings to a typical school sample, using multiple measures of fluency (single-word and text) to ensure that results do not reflect the use of particular assessments.

With regard to theoretical interpretation of the current findings, the RAN task would appear to relate most closely to the operation of the lexical mechanism of the DRM (Coltheart et al., 2001). As noted previously, exception word reading accuracy, which is associated with RAN performance, cannot be achieved through the application of grapheme-phoneme decoding rules (a non-lexical strategy), but rather, relies on the ability to access a word's lexical representation in memory and "read out" its pronunciation. Presumably, it is this efficient, direct lexical reading strategy that also enables fast and accurate reading of text, because it obviates the need for decoding.

By contrast with the observed differences between groups of children who were distinguished on the basis of RAN ability compared to PA ability, performance on an assessment of single-word and nonword reading fluency revealed superficially similar group effects. Thus, children with higher RAN scores achieved better single-word and nonword fluency results than children with lower RAN scores; and children with higher levels of PA achieved better fluency results than children with lower levels of PA. However, these group differences may stem from different underlying weaknesses. Thus, performance on the word and nonword fluency tasks relies on both decoding accuracy (associated with PA) and response speed (associated with RAN). Consequently, further research is required in order to shed additional light on interpretation of these findings.

Two variables that did not reveal a significant effect of RAN ability were silent reading rate for passages and orthographic recognition. One possible interpretation of these null results is that RAN is more strongly associated with oral reading assessments than with silent reading assessments because of their shared articulation component (Georgiou, Parrila, Cui & Papadopoulos, 2013; Papadopoulos, Spanoudis & Georgiou, 2016). There is a less interesting alternative possibility, however. Since both of these measures (silent passage reading and orthographic recognition) are completed silently, the examiner has no way of knowing exactly what participants are doing during the tasks. Participants may well be completing the tasks according to the instructions provided, but this cannot be taken as a certain. Therefore, results of such tasks need to be evaluated with caution.

Limitations and future research

A possible limitation of this study lies in the homogeneous nature of the participant sample. The children came from a medium socio-economic, Anglo-Saxon area with caregivers generally being well-educated (most having 13+ years of education). Whilst this sample has advantages in reducing variability, it also does not reflect wider school populations. Future research should replicate the findings in a larger sample containing a more diverse school population in terms of ethnicity and socio-economics.

A second limitation is the high number of children omitted due to low nonverbal ability (NVIQ < 80). On average, approximately 10% of children would be expected to attain scores below 80, but in the current sample, the figure was much higher, at just over 20% (16 out of 74). Although it is unclear why more children than expected scored below the imposed cut-off, it is reassuring that scores achieved by the included participants were, on average, as expected.

Practical implications for classroom teachers

Importantly, this study helps to address the question for classroom teachers, as to which assessment strategies will prove most useful for planning differentiated instruction and targeted intervention, particularly for those students whose reading might not yet extend to passages of text. For one thing, although Meisinger et al. (2010) found that word reading measures (real and nonwords) alone, are insufficient for identifying children who may struggle with reading at the text level, our results suggest that screening of exception word reading, in particular, could be informative in this regard. More importantly however, the current results show that a screening assessment inclusive of both PA and RAN could be useful to inform classroom teachers who are engaged in planning more effective intervention. For example, those children displaying deficits in RAN would most likely benefit from interventions that explicitly train automaticity (e.g., RR); those with single PA deficits would benefit from explicit, systematic training in PA and/or nonword decoding; and those with a double-deficit would benefit from a combination of instruction in PA and RR. Whilst further research is warranted in terms of whether such specific subtyping and targeted intervention would in fact assist students in achieving improved reading outcomes, these results appear promising for increasing teacher knowledge in terms of (1) how to assess fluency; and, (2) the benefits of using the RAN task in a battery of assessments.

Conclusion

In conclusion, the significance of teachers' understanding why some children achieve fluency while others do not cannot be overstated. Such understanding will ultimately influence teachers' ability to plan effective assessment, quality instruction, and targeted intervention as necessary. The findings of this research underscore the importance of ensuring that the assessment battery we use to diagnose reading difficulties in our students incorporates all aspects of reading, including fluency. More specifically, inclusion of a RAN task is recommended, especially in situations where it is not possible to use a passage level task, for example, with young readers. Adopting this approach should improve early identification of reading problems and inform decision making in terms of targeted intervention.

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CHAPTER FOUR

REPEATED READING OF WORDS AND PASSAGES IMPROVES FLUENCY BUT NOT RAN

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Statement of authorship. The first author Joanne Fitzgibbon was responsible for the conception of the project under the guidance of Professor Linda Cupples and Dr Caroline Law (primary and associate supervisors). Mrs Fitzgibbon took responsibility for all data collection, initial data analyses, writing of all first drafts, and co-writing of all subsequent and final drafts. As primary supervisor, Prof Cupples contributed to the oversight of all aspects of the research, provided instruction and guidance for final data analyses, and co-wrote final manuscripts. As associate supervisor, Dr Law contributed to the oversight of all aspects of the research and co-wrote final manuscripts.

Abstract

Becoming a fluent reader can prove challenging for some students, as it is not a natural process like speaking, but rather a complex set of skills that requires explicit, systematic instruction. The aim of this study was to evaluate the effectiveness of Repeated Reading (RR) for a group of middle-to-late primary-school-age children who displayed accurate single-word decoding skills, and average to below-average reading fluency. Participants were 20 native English-speaking Australian students in grades 3-6: 13 were assigned to one of two treatment groups (immediate or delayed) and the remaining 7 were allocated to a "no-treatment" control group. All children's reading was monitored over the course of the 3-month study; but only treatment children received RR for a short, 4-week period using both single-words and passages of connected text for training purposes. Results indicated immediate gains in reading rate of trained and matched, untrained passages for treatment but not control children after RR of single-words and passages, although larger improvements were evident after passage training. Beneficial effects of RR did not appear to generalise to other reading or reading-related measures, with observed improvements (including comprehension of unfamiliar passages, single-word and non-word reading fluency, and non-word reading accuracy) evident in both treatment and control groups. While further investigation is needed into which components of RR provide the greatest generalisation effects, current findings add to the literature to date, which suggests that RR is suitable for inclusion in a classroom reading instruction program.

Introduction

The behavioural and psychological issues associated with difficulties in learning to read have been well-established in the literature. They include an inability to fully participate in classroom learning opportunities, reduced employment and social opportunities, self-efficacy problems, and far-reaching anti-social behaviours (Bullis & Walker, 1994; Morgan, Farkas, Tufis, & Sperling, 2008; Smart, et al., 2017).

While the ability to accurately identify written words, sentences, and passages is essential for successful reading development, it is not sufficient. The ultimate goal of reading instruction during the primary school years is to create skilled, independent readers who are able and eager to read for learning and for pleasure (Schwanenflugel, et al., 2006). However, this goal is unlikely to be achieved if reading is slow and effortful, regardless of accuracy. At this and subsequent stages of learning, therefore, the importance of competent fluency traits in reading should not be underestimated, because poor fluency is a reliable predictor of future reading comprehension difficulties (Stanovich, 1991). Furthermore, children who read too slowly often take longer to complete in-class and homework assignments than more skilled readers, and often do not even complete work (Adams, 1994; Moats 2001; Pikulski & Chard, 2005; Rasinski, 2000), thus contributing to low literacy and poor academic attainment. It stands to reason that well-planned targeted instruction is as important for enhancing fluency as it is for improving decoding accuracy.

Despite the important role of reading fluency in children's academic success, the U.S. National Reading Panel (NRP; NICHD 2000) identified the teaching of fluency as the "most neglected" reading skill (see also Allington, 1983). In this regard, it is well established that decoding can be taught successfully through explicit, systematic phonics training (Duff & Clarke, 2011; Ehri, Nunes, Stahl & Willows, 2001), but improvements in reading speed and automaticity are often more difficult to achieve (Lyon & Moats 1997). According to Moats (1999), becoming a fluent reader can prove challenging for some students, as it is not a natural process like speaking, but rather a complex set of skills that requires explicit, systematic instruction. In the current study, we investigated the effectiveness of a commonly used instructional practice for improving children's reading fluency, Repeated Reading (RR; National Reading Panel, 2000; Samuels, 1979).

What is reading fluency?

Various definitions of reading fluency have been offered in the literature to date. Some examples include: the ability to decode rapidly and accurately (Armbruster, Lehr & Osborn, 2001); the ability to recognise words automatically and read with accurate phrasing (Hudson, Lane & Pullen 2005; Kuhn, Schwanenflugel & Meisinger, 2010); and the ability to simultaneously decode and comprehend (Alt & Samuels, 2011; LaBerge & Samuels, 1974). A more detailed definition was provided by Meyer and Felton (1999), namely: "the ability to read connected text rapidly, smoothly, effortlessly and automatically with little conscious attention to the mechanics of reading such as decoding" (p. 284). Common to these various definitions is a general consensus that assessment of reading fluency should encompass aspects of oral reading rate and accuracy. Thus, for the purpose of this study, fluency was measured simply in terms of the number of words read correctly per unit time.

This approach is consistent with use of a curriculum-based measure (CBM), which provides a quick assessment of a student's academic proficiency in a specific task. Frequently used to assess oral reading fluency, students read text aloud for one minute, and the number of omissions, substitutions and words read correctly is recorded. The result provides an accepted valid and reliable measure of accuracy and rate of reading (Fuchs & Fuchs 1992).

Reading fluency, decoding accuracy, and rapid automatised naming (RAN)

Adopting an operational definition of fluency as words read correctly per unit time raises the question of how fluency relates to measures of single-word oral-reading *accuracy* on the one hand, and *speed* of orthographic processing on the other. In regard to the first of these aspects the dual-route model of single-word oral reading (DRM; Coltheart, Rastle, Perry, Langdon & Ziegler, 2001) incorporates two cognitive processing mechanisms for converting print to speech: a non-lexical process, which involves the application of letter-sound rules; and a lexical process, which involves recognising a word's orthography and retrieving its associated phonological representation directly from memory. These two routes are essential for reading different types of words. Exception words, such as "meringue," do not follow English spelling-sound rules, and hence can only be read correctly via the lexical route. By contrast, nonwords, such as "marrong" are not associated with lexical entries, and so can only be read correctly via the non-lexical route. Furthermore, according to this model, skilled readers are highly proficient in reading via the (more direct) lexical route. It follows that enhanced reading fluency should be more closely associated with accurate reading of exception words than nonwords.

With regard to the association between reading fluency and speed of orthographic processing, the double deficit hypothesis (DDH) of Wolf and Bowers (1999) is relevant. According to the DDH, some children are accurate readers, but experience fluency difficulties as a result of a singular deficit in rapid automatized naming (RAN; the ability to name quickly and accurately a set of visually presented, highly familiar symbols). One interpretation of this observed association between RAN and fluency attributes it to a shared association with orthographic processing (Bowers, Golden, Kennedy & Young, 1994; Clarke, Hulme, & Snowling, 2005; Manis, Doi, & Bhadha, 2000). On this view, orthographic knowledge, demonstrated by quickly and accurately recognising letters and letter patterns in words, is an important contributor to passage reading fluency, which relies on the accurate and rapid recognition of words in text (Barker, Torgesen, & Wagner, 1992; Ehri, 2005; Perfetti, 1992). It follows that enhanced reading fluency should be associated with improvements in orthographic processing speed and hence the RAN task.

What is RR?

The overarching focus of this research was to investigate the effectiveness of RR for improving reading fluency. RR has been used over many years to remediate reading difficulties. Samuels (1979) described this approach as, "a supplemental reading program that consists of re-reading a short and meaningful passage until a satisfactory level of fluency is reached" (p. 404). A growing body of research suggests that RR may be effective in remediating fluency deficits because it incorporates practice on all aspects of reading fluency, thereby improving automaticity in reading and enabling better text reading comprehension (e.g., Gellert, 2014; Kuhn, 2010; Meyer & Felton, 1999; Samuels, 2006; Therrien, 2004; Therrien & Kubina, 2006). An alternative suggestion is that observed improvements may result purely from the increase in time spent reading, which is associated with a program of RR, rather than any specific instructional characteristics associated with RR of text (Kuhn & Stahl, 2003).

Implementation of RR

Following on from the previous point, although RR is a widely-used, evidenced-based intervention for improving reading fluency, there is some disagreement as to the aspects that make it most effective (Chard, Ketterlin-Geller, Baker, Doabler & Apichatabutra, 2009; Chard, Vaughn, & Tyler, 2002). In an effort to identify the crucial instructional components, Therrien (2004) conducted a meta-analysis. On this basis, he recommended that RR intervention was most effective under the following conditions. (1) Students read the text aloud to adults, rather than peers. (2) A cue was provided (e.g., to read for speed and comprehension). (3) Texts were re-read three to four times (although a subsequent study by Ardoin, Williams, Klubnik, and McCall [2009] found that six readings produced greater maintenance effects than three). (4) Corrective feedback was provided on word errors. (5) A performance criterion was used, for example, number of words read correctly per minute (e.g., Hasbrouck & Tindal, 1992), or reading a passage within an allocated time (e.g., Pany & McCoy, 1988; Therrien & Kubina, 2006).

Other recommendations in the literature include the use of sessions lasting10-20 minutes, three to five times per week (Therrien & Kubina, 2006); and the provision of corrective feedback on oral reading errors after 3-4 seconds or at the end of the passage to avoid error practice. Feedback on performance, for example, "Well-read Tobi, you read 122 words and only made 2 errors," has also been shown to improve reading performance and motivate readers. Graphing results for number of words read has also improved performance, as has re-reading of relevant sections where errors occurred and the inclusion of decoding activities where appropriate, to assist with correct reading on subsequent occasions (Hudson et al., 2005).

In addition to these potentially important procedural aspects of RR, successful implementation relies on appropriate choice of materials for re-reading. Essential materials include either medium-length instructional level passages (i.e., passages that are within 85-95% of a reader's word accuracy level), or word lists. An important question for practitioners and researchers alike is whether improvements in reading fluency differ according to the materials used for re-reading, in particular, single-words (word lists) or connected text (passages). Many studies reported that RR for single-words using delivery modes such as words lists, flashcards or computer screens had a positive effect on reading trained words (Fleisher, Jenkins and Pany, 1979), on reading the same words in connected text (Levy, Abello and Lysynchuk, 1997; Meyer and Felton, 1999; Tan & Nicholson, 1997); and on fluency deficits in general (Torgesen & Hudson, 2006). Other studies found that RR at the passage level was a more effective method for enhancing reading fluency (Faulkner & Levy, 1994; Martin-Chang & Levy, 2005; Rashotte & Torgesen, 1985; Therrien & Kubina, 2007) or that both types of training were beneficial. In a study involving 86 English-speaking students from grades 2 to 5, Ring, Barefoot, Avrit, Brown and Black (2013) compared RR at word and passage level. Findings showed that both types of training resulted in passage fluency gains. However, no significant benefits of either RR training were found for sight-word reading fluency, as measured by the Sight Word Efficiency (SWE) subtest from the Test of Word Reading Efficiency – 2nd edition (TOWRE-2; Torgesen, Wagner & Rashotte, 2012).

In an earlier study that compared the effectiveness of RR using different stimulus materials, Fleisher et al. (1979, Experiment 2) trained poor comprehenders in grades 4 and 5 in either single-word reading or phrase reading. Results for these two treatment groups were compared to those for two control groups, one comprising good comprehenders and the other comprising poor comprehenders, neither of whom received training in RR of words or phrases. In this experiment, single-word training involved RR of all the words from a target passage using both flashcard and word list training until a criterion rate of 95 wpm was achieved. Phrase training involved students repeatedly reading a list of randomly ordered phrases from a target passage until a rate of 160 wpm was met. During a post-test phase students were asked to read a word list and passages containing the trained words and/or phrases and to complete various comprehension tasks, including an oral cloze task. Results showed that RR of either words or phrases improved reading fluency for the trained words presented in isolation, although single-word training was more effective than phrase training. On the other hand, there were no effects of treatment on passage reading speed suggesting that training of words or phrases in isolation may not be sufficient to improve reading fluency in context. With regard to comprehension, the only significant effect of RR was seen on the oral cloze task, where phrase-training was more effective than single-word training. The authors attributed this finding to the poor readers being trained on the exact phrases that appeared in the passage, rather than to improvements in comprehension more generally, since no other comprehension measures revealed a significant group difference.

Levy et al. (1997) conducted two experiments that they described as “conceptual replications” (p. 175) of Fleisher et al.’s (1979) experiments. In particular, Levy et al. investigated whether RR of single-words resulted in benefits for passage reading when passages contained trained versus untrained words. In two experiments, different samples of 4th grade students with poor word identification skills engaged in RR of randomised lists of words taken from a target passage. The words were presented on a computer screen and read 6 times per day, over 4 days (in Experiment 1) or 5 times per day over 4 days (in Experiment 2). On the fifth day, students were assessed on their speed and accuracy in reading two stories: one that contained the trained words and a second that contained untrained words. Comprehension was also assessed for both passages. Results of the first experiment showed that participants were faster and more accurate to read passages containing trained words than passages containing untrained words, but no significant difference in comprehension was evident. By contrast, in the second experiment participants exhibited better comprehension of passages containing trained than untrained words, in addition to an advantage in passage reading speed and accuracy. According to Levy et al., one factor that may have contributed to their failure to find an effect of RR on passage comprehension in their first experiment was that only a subset of the most difficult content words (72 from approximately 91) were trained. It is possible therefore that conceptual processing of passages was impeded by the untrained content words. By contrast, all content words from the target passage were trained in Experiment 2. Regardless of why effects on comprehension differed, however, the findings from this study are consistent with others showing that tasks providing repeated practice of single-words in isolation can lead to fluent recognition of words in context.

Further support for this association comes from a study by Tan & Nicholson (1997). A sample of 42 children, ages 6 – 10 years, with below average passage reading comprehension were allocated to 3 groups of 14 participants according to chronological age, comprehension scores, and reading age (matched within 5 months). The groups were assigned to flashcard training, phrase training, or a no training condition. The results were similar to those reported by Levy et al. (1997), in that comprehension improved significantly for both intervention groups when compared to the control group, regardless of whether they were trained on single-words or phrases/sentences.

Although the evidence described here suggests that RR for single-words can be effective in improving passage reading fluency, other findings showed that RR of connected text results in stronger immediate gains in reading fluency for both good and poor readers (Martin-Chang & Levy, 2005; Therrien & Kubina, 2007). Martin-Chang and Levy, found that RR involving either isolated word training or passage training resulted in improved reading fluency for two participant samples, one a group of good and poor readers in grade 4, and the other a group of average readers in grade 2. The results of their first experiment (with grade 4 children) confirmed that RR for single-words or passages resulted in faster reading of an unfamiliar passage that contained trained words compared to an unfamiliar passage that contained new words. However, improvements in reading rate as a result of RR training were more marked when children received passage reading training. The results from their second experiment (with grade 2 children) demonstrated further that RR of passages improved children's passage reading accuracy and rate to a greater extent than did RR of single-words. In interpreting their findings, Martin-Chang and Levy suggested that reading words in context, as opposed to isolation, might assist in the establishment of stronger lexical representations as a result of the increased involvement of semantic processes, and thus enable more efficient single-word recognition subsequently.

Although a number of past studies have demonstrated immediate beneficial effects of RR on children's oral reading fluency for directly trained materials or materials containing a high degree of overlap with trained words, analogous effects on untrained passages have been less convincing (Faulkner & Levy, 1994; Rashotte & Torgesen, 1985). In fact, Rashotte and Torgesen showed that re-reading connected text did not improve children's ability to read unfamiliar passages, but rather led to an improved ability to read passages containing previously trained words.

Ardoin, Eckert and Cole (2008) also examined whether benefits for oral reading fluency from RR of passages would generalise to unfamiliar texts. A sample of 42 grade 2 and grade 4 students with varying reading skills received two treatments, the order of which was counter-balanced across different participants. RR treatment involved a first oral reading to the students by the examiner; followed by three readings of the same passage by the students. The Multiple Exemplar treatment also involved a first oral reading by the examiner, which was followed by the student reading three versions of the passage, two of which were modified by changing sentence order, changing word order within sentences, and replacing some words with antonyms or synonyms. Results during training showed that although RR significantly improved students' oral reading fluency on trained passages, the Multiple Exemplar condition did not. By contrast, however, Multiple Exemplar treatment produced a greater improvement in fluency for generalisation passages, but only when those passages were developed with medium word overlap; that is, when they contained 55-65% of the same words as the intervention passages. For generalisation passages with high word overlap (85-95% of the same words) there was no difference between the treatment conditions. Ardoin et al. concluded that generalisation may be enhanced by requiring students to read different, as opposed to the same, passages.

Improvements in comprehension

As illustrated above, reports in the literature consistently indicate improvements in reading fluency linked to RR; however, the evidence is not as clear for associated improvements in reading comprehension. Some studies report moderate gains in comprehension compared to larger gains in reading speed on trained passages (see Therrien, 2004, for a review), whereas other studies found only minimal or inconsistent improvement in reading comprehension (Levy et al., 1997; Rashotte & Torgesen, 1985). This variation may be explained partly in terms of proficient comprehension requiring many cognitive and linguistic processes working together (NICHD, 2000). Although RR is a commonly used instructional practice to remediate difficulties associated with reading fluency (accuracy, speed, and expression), if a student's failure to comprehend is not a direct consequence of a fluency deficit, then RR would be expected to have minimal impact on reading comprehension. Consistent with this view, although some RR studies report strong links with comprehension, this association is often as a consequence of improved performance in reading rate (Jenkins, Fuchs, van den Broek, Espin & Deno, 2003; Levy et al.1997; Perfetti & Hogaboam, 1975). In fact, gains in comprehension are often evident in an intervention design that includes both RR of connected text, and specific treatment of comprehension, which encourages readers to monitor their understanding of text as they read (e.g., Therrien, Wickstrom & Jones, 2006). In a similar vein, other studies have found that RR of single-words contributes to later reading comprehension (Tan & Nicholson, 1997), although this improvement occurs after attending to other reading difficulties (e.g., defining unfamiliar words, providing decoding activities to teach words read incorrectly, and ensuring passages are at the students' current reading level in order to allow for improvements in fluency to enable gains in comprehension) (O’Connor, White and Swanson, 2007; Therrien & Kubina, 2006; Therrien et al., 2006).

Improvements in RAN

If, as suggested earlier, RR results in more fluent reading because it improves the efficiency of orthographic processing, then it might be expected that RR would also result in improved RAN performance (Bowers, 1993; Wolff, 2014). In line with this proposal, Bowers reported gains in both reading fluency and RAN from repeated practice of passages in a study involving slow readers from grades 2 to 4. Support also comes from Wolff, who examined PA and RAN as independent predictors of reading rate, comprehension, and spelling; and discovered that RR training led to a significant improvement in RAN, which bore a reciprocal relationship to reading speed. Conversely, other investigators have found no direct or indirect effects on RAN performance following training to improve reading fluency (Kirby, Georgiou, Martinussen & Parrila, 2010; Norton & Wolf, 2012). Given the inconclusive nature of these findings, further investigation of the possible impact of RR instruction on RAN performance is warranted.

Interim summary

To summarise, past research indicates that RR is a worthwhile instructional approach to assist in promoting children’s reading fluency. While there is broad agreement in the literature that training single-words or connected text can result in immediate gains in children’s reading fluency, debate continues as to whether such improvements transfer only to passages containing the trained words, or also to passages with unfamiliar content, and whether improvements generalise to subsequent reading capabilities overall. There is also disagreement about whether it is more effective for children to practise single-words or passages of connected text. Considering that RR is a popular and widely-used intervention for children with reading fluency deficits, further investigation into these various aspects is warranted.

The current study

The aim of this study was to evaluate the effectiveness of RR for a group of middle-to-late primary-school-age children of mixed-ability. All participants selected for inclusion displayed accurate single-word decoding skills, because such children are most likely to exhibit benefits of fluency training. Primary outcome measures included passage reading fluency (words correct per minute), and reading fluency for single-words and nonwords. A subsidiary aim was to explore whether the materials used for training (single-words or passages of connected text) would affect the strength of immediate gains (on trained passages). Generalisation (transfer) effects were investigated using untrained passages that were matched closely to those used for training (matched, untrained passages), three additional fluency measures (for single-words, nonwords, and passages that resembled training materials less closely), and RAN for digits. Also incorporated were measures of single-word and non-word reading accuracy and PA, which were not expected to show effects of RR treatment.

Research questions and hypotheses

Four research questions (RQs) were addressed.

1. Is RR effective in improving reading rate of trained and/or matched, untrained passages?
2. If RR is effective in improving reading rate, do its effects differ as a function of training materials (single-words vs. connected text)?
3. Do effects of RR generalise to measures of untrained single-word and non-word reading fluency?

4. Do effects of RR generalise to a popular measure of passage reading comprehension (NARA-3), RAN, single-word and non-word reading accuracy, or PA?

We hypothesised that children with average reading fluency and adequate single-word decoding skills, who received weekly treatment in the form of RR, would improve their reading rate on trained and matched, untrained passages (RQ1). We hypothesised further, that RR of both single-words and passages of text would be effective in improving children's reading fluency, although in accordance with Martin-Chang and Levy (2005), RR of passages would be more effective than RR of single-words (RQ2). In the absence of strong evidence to the contrary, we hypothesised further that RR would result in improved reading fluency for single-words and nonwords (RQ3). Finally, regarding RQ4, we hypothesised that, in accordance with Fleisher et al. (1979) and Martin-Chang and Levy (2005), improvements in children's reading comprehension would *not* be evident post treatment. Similarly, we hypothesised that improvements would not generalise to measures of single-word and non-word reading accuracy or PA. Enhanced RAN performance was, however, expected as per Bowers (1993) and Wolff (2014).

Method

Participants

Participants in this study were 20 primary school students, 10 males and 10 females, in grades 3 to 6. They were selected from a sample of 74 children who were recruited approximately 2 years earlier for a larger investigation into children's reading fluency. All children attended the same independent school within a medium socio-economic area north of Sydney, Australia. They were native speakers of English, with normal hearing, normal or corrected-to-normal vision, and no known history of neurological disorder. Children were not excluded on the basis of a previous diagnosis of attention deficit/hyperactivity disorder. They were excluded, however, on the basis of: (1) a nonverbal IQ < 70 (*n* = 6); (2) having left the school prior to commencement of the treatment phase (*n* = 11); (3) achieving a score outside the typical range (i.e., below the 20th percentile) on regular words, exception words, or nonwords included in the Coltheart and Leahy (1996) oral reading test (described below under "Measures;" *n* = 33); (4) a prior diagnosis of Irlen Syndrome and currently using coloured lenses (*n* = 1); or, (5) not returning consent forms on time (*n* = 3).

Within the included sample of 20 students, three groups were formed. Two treatment groups, one immediate and the other delayed, included 13 participants in total from grades 3 (*n* = 4), 4 (*n* = 1), 5 (*n* = 5), and 6 (*n* = 3), with a mean age of 10;5 (years;months). The remaining 7 participants were allocated to a "no-treatment" control group, which included children from grades 3 (*n* = 4), 5 (*n* = 2) and 6 (*n* = 1), with a mean age of 9;11. As noted above, all included participants exhibited adequate oral reading skills for single-words and nonwords, scoring above the 20th percentile on regular words, exception words, and nonwords on the Coltheart and Leahy (1996) assessment. At the time of original recruitment, participants in the treatment groups exhibited average or below average sight-word reading fluency, with scores from the 18th to the 81st percentile (*Mean* = 57.8) on the SWE subtest of the TOWRE-2 (Torgesen et al., 2012; see task description below under "Measures"). Children allocated to the "no-treatment" control group attained consistently better SWE scores (from the 84th to the 94th percentile; M*ean* = 87.7) in all but one case. The one exception was a child who scored at the 75th percentile on the SWE, but the 95% percentile on the rate measure from the Neale Analysis of Reading Ability – 3rd Edition (NARA-3; Neale, 1999; see task description below under "Measures"), thus suggesting that her reading fluency was underestimated on the SWE.

Caregivers provided informed consent for participation of students who met the selection criteria for the treatment or control groups. A parental survey completed for the larger study provided additional relevant background information. Intervention for learning difficulties at school and/or previous referral to a speech pathologist was reported for 3 of the 20 participants. Prior intervention for learning difficulties at school was reported by 3 caregivers for either themselves or an additional child. Caregivers were generally well-educated, with all having 13+ years of education. When asked to describe at-home reading activities with their children, either school-related or for leisure, most caregivers reported participating in some or all such activities several times per week. At the conclusion of intervention, caregivers were provided with a report of their own child's results.

Measures

All participants completed a battery of standardised and non-standardised assessments pre- and post-treatment to measure a wide range of variables associated with fluent and accurate reading. More specifically, participants' reading outcomes were assessed using measures of: passage-reading accuracy, rate, and comprehension; real word and non-word reading fluency (speed and accuracy); rapid naming (RAN for digits); oral reading accuracy (of exception words and nonwords); orthographic recognition (lexical decision); and PA (phoneme isolation). Background variables included in the study were: non-verbal cognitive ability and receptive vocabulary.

Pre- and post-treatment measures

Passage Reading - accuracy, rate and comprehension.

The NARA-3 (Neale, 1999) was administered as per instructions in the test manual to assess participants' oral reading accuracy, speed, and comprehension at the passage level. Students were timed as they read the passages aloud, but no time limit was imposed. The NARA-3 contains two parallel test forms, each of which contains six passages of increasing difficulty. Form 1 was administered pre-treatment and Form 2 post-treatment. Students progress through each passage until 16 oral reading errors are made in a single passage (accuracy score based on number of words read correctly). Raw scores and percentile ranks were calculated according to instructions in the test manual for description and analysis pre- and post- treatment.

The Wheldall Assessment of Reading Passages (WARP; Wheldall, 1996) comprises a selection of 200-word parallel passages designed for a reading level of grades 2 to 5. Three initial assessment passages (A, B, C) and 10 progress monitoring passages are included. In this study, the initial passages were administered to assess oral reading performance pre- and post-treatment. Participants were asked to read each passage aloud for 1 minute. Raw scores were calculated as the number of words read correctly in that minute (wcpm). Average scores were computed across the three initial passages and used for description and analysis purposes pre- and post-treatment. Eight of the 10 progress monitoring passages were used for RR treatment as described below (under "Design and Procedure").

Word and non-word reading fluency.

The TOWRE-2 (Torgesen et al., 2012) was used to measure oral reading fluency for sight-words and nonwords. This test contains two subtests: the sight word efficiency test (SWE) and the phonemic decoding efficiency test (PDE). SWE measures participants' ability to read words as whole orthographic units accurately and quickly; whereas PDE measures the ability to use grapho-phonic (letter-sound) knowledge to decode unfamiliar letter strings (nonwords) efficiently, with accuracy and speed. Stimuli are presented in list format, and participants are asked to read aloud as many real words or nonwords as possible in a 45-second period. Practice lists of 8 words and 8 nonwords are completed prior to the test proper. The TOWRE-2 contains 4 parallel test forms, A to D. In this study, Form A was administered pre- and post-treatment; and Forms B to D were used to monitor progress during the treatment period. Raw scores (calculated as the number of words or nonwords read correctly within the allocated time) and standard scores (distributed with a mean of 100 and standard deviation of 15) were used for description and analysis purposes.

Word reading accuracy.

The Coltheart and Leahy Reading Test (1996) was administered to assess children's oral reading of regular words, exception words, and pronounceable nonwords. All words and nonwords (30 items of each type), were presented on individual cards and participants were asked to read each one aloud. No time limit was imposed. Raw scores (calculated as the number of exception words and nonwords read correctly out of 30) were used for description and analysis purposes pre- and post-treatment; and percentile ranks on all three word types were used as a selection criterion.

The Orthographic Choice Task (Olson, Wise, Conners, Rack & Fulkner, 1989) was used as a second measure of word reading accuracy to assess participants' knowledge of orthography. Participants were provided with 52 word/non-word pairs (e.g., bark / barc) and asked to point to the real word from each pair. Students must use their knowledge of word-specific spellings to respond correctly as both items within a pair have the same pronunciation when decoded using letter-sound rules. Children's scores (calculated as the number of correctly selected real words out of 52) were used for description and analysis purposes pre-and post-treatment.

RAN.

The Rapid Automatized Naming and Rapid Alternating Stimulus Test (RAN/RAS; Wolf & Denckla, 2005) was administered to assess participants rapid naming skills. For this assessment, participants are asked to name 50 randomly ordered stimuli arranged in 5 rows of 10 as quickly and accurately as possible from left to right and top to bottom. Prior to the test, 2 rows of 5 items are completed for practice. A raw score is obtained by recording the time in seconds to name all 50 items in the subtest. In the current study, the digit naming subtest was used because results from previous studies showed that beyond kindergarten, alphanumeric RAN is a stronger predictor of current and/or future reading abilities (Clarke et al., 2005; Misra, Katzir, Wolf & Poldrack, 2004). Raw scores and standard scores (distributed with a mean of 100 and standard deviation of 15) were used for description and analysis purposes pre- and post-treatment.

***PA*.**

The Comprehensive Test of Phonological Processing – Second edition (CTOPP-2; Wagner, Torgesen & Rashotte, 2013*)* was administered to examine treatment effects on PA. The *Phoneme Isolation (PI*) core test was used, during which participants isolate individual sounds within words. Testing was discontinued after three consecutive incorrect responses. Raw scores (calculated by adding the number of correct responses) and standard scores (distributed with a mean of 10 and standard deviation of 3) were computed and used for description and analysis purposes.

Background Tasks

Non-verbal cognitive ability.

The Wechsler Non-verbal Scale of Ability (WNV; Wechsler & Naglieri, 2006), was administered according to instructions in the test manual to assess for nonverbal cognitive ability. All participants completed the matrices subtest in which they were asked to choose one possible option from a range of pattern pieces to correctly complete an incomplete grid. Participants also completed one other sub-test, depending on their age: Children up to 7;11 (years; months) completed the recognition subtest, whereas children aged 8;0 and above completed spatial span. Full scale scores (distributed with a mean of 100 and standard deviation of 15) were computed for description and analysis purposes. Participants with a nonverbal IQ <70 were excluded from the study.

Receptive vocabulary.

The Peabody Picture Vocabulary Test - Fourth Edition (PPVT-4; Dunn & Dunn, 2007) was administered to obtain a measure of children's receptive vocabulary. Participants are presented with a set of four pictures on each trial. The examiner says a word that describes one of the pictures, wherein the examinee is asked to point to the picture that best represents the spoken word. In the current study, raw scores (number of correctly identified pictures) were used to obtain standard scores, distributed with a mean of 100 and standard deviation of 15, which were used for description and analysis purposes.

Treatment passages

Eight of the 10 progress monitoring passages from the WARP (Wheldall, 1996) were used for both RR treatment and to evaluate progress during treatment (weeks 3, 5, 7 and 9). Raw scores were calculated as the number of words read correctly per minute, with average performance over relevant passages used for analysis purposes.

Design and Procedure

An experimental design was implemented to compare the effects of RR in three groups of participants: two who received treatment and one control group. All groups underwent pre-testing in week 1 of the study and post-testing in the final week. Table 1 provides a detailed treatment timeline according to group. In essence, their treatment differed as follows.

- Group 1 received *immediate* RR treatment in the 4 weeks that followed pre-testing (i.e., weeks 2 to 5), with RR for single-words preceding RR for passages of connected text. On completion of treatment, this group's progress was monitored fortnightly for the following 4 weeks (i.e., weeks 6 to 9).
- Group 2 acted as a *delayed* treatment control group. Their progress was monitored fortnightly during the first 4 weeks that followed pre-testing (i.e., weeks 2 to 5). On

completion of this extended baseline period, group 2 received RR treatment for 4 weeks (i.e., weeks 6 to 9), with RR for passages of connected text presented before RR for single-words.

- Group 3 was a fluent *control* group who received no treatment. They took part in pre- and post-assessments and four fortnightly monitoring sessions, which mirrored those for children in the treatment groups.

All pre- and post-testing, and treatment sessions took place in a quiet space during school hours in the previously described school. The first author, who had previous experience as a learning support teacher with similar intervention designs, conducted all assessment and treatment sessions. Pre-and post-treatment sessions lasted one hour each. All sessions were audio recorded for scoring and reliability purposes; and a stopwatch was used for timing purposes where appropriate.

Ethical approval for the research was granted by the Macquarie University Human Research Ethics Committee, and written permission was obtained from all caregivers prior to the first testing session. In addition, students' verbal assent was obtained prior to the commencement of each session, and they were assured that they could withdraw from the study at any time by requesting to do so or asking to return to their classroom.

RR Treatment

After meeting the selection criteria for treatment (i.e., average to below-average single-word reading *fluency* and average or above average reading *accuracy* for words and nonwords on recruitment to the larger study), students were assigned to either the *immediate* or *delayed* treatment group. All treatment was administered during weeks 2-9 of Term 3 (July-September). The program consisted of pre- and post-treatment assessments (first and final weeks); 4 weeks of RR targeting isolated words (word lists) for 2 weeks, and words-in-context (passages) for 2 weeks; and monitoring periods of 4-week's duration either before treatment (delayed group) or after treatment (immediate group).

During RR for isolated words, participants were presented with word lists containing all 200 content and function words from a chosen progress passage and asked to "read these words across the page (row by row) as quickly and accurately as you can." During RR for passages (words-in-context), participants were presented with a 200-word story at or below their current reading level (one of the eight WARP progress monitoring passages) and asked to "read the story as quickly and accurately as you can." Accuracy (number of errors) and rate (wcpm) scores were computed for each word list or passage of connected text and reported back to the students after each of their three re-readings. Each participant received three 15-minute sessions per week for 4 weeks. Results were graphed (in accordance with a suggestion by Hudson et al., 2005).

Interim post-tests were conducted after each period of RR treatment. Following RR of isolated words, participants read two passages containing trained words and an additional passage containing unfamiliar/untrained words; and following RR of passages, participants read the two passages on which they had been trained, and an additional unfamiliar/untrained passage. They were instructed to read all passages as quickly and accurately as they could, but in order to encourage them to also read for meaning, they were asked six comprehension questions about the unfamiliar/untrained passages in both conditions: answers to five questions were directly stated, and one was inferential. Control participants' reading was monitored in the same manner throughout the treatment period but with no treatment provided (see Table 1).

Table 1. Treatment timeline according to group

Week	Immediate Treatment (Grp 1)	Delayed Treatment (Grp 2)	No Treatment (Grp 3)
1	Pre-testing WARP passages A, B, C TOWRE-2 SWE, PDE	Pre-testing WARP passages A, B, C TOWRE-2 SWE, PDE	Pre-testing WARP passages A, B, C TOWRE-2 SWE, PDE
2	SW RR passage 1		
3	SW RR passage 2		
End wk 3	Interim post-testing Trained words: passages 1, 2 Untrained words: passage 3[a] TOWRE-2 SWE, PDE	Ongoing monitoring Untrained passages 1, 2, 3[a] TOWRE-2 SWE, PDE	Ongoing monitoring Untrained passages 1, 2, 3[a] TOWRE-2 SWE, PDE
4	Passage RR passage 4		
5	Passage RR passage 5		
End wk 5	Interim post-testing Trained passages 4, 5 Untrained passage 6[a] TOWRE-2 SWE, PDE	Ongoing monitoring Untrained passages 4, 5, 6[a] TOWRE-2 SWE, PDE	Ongoing monitoring Untrained passages 4, 5, 6[a] TOWRE-2 SWE, PDE
6		Passage RR passage 4	
7		Passage RR passage 5	
End wk 7	Ongoing monitoring Trained passages 2, 5 Untrained passage 8[a] TOWRE-2 SWE, PDE	Interim post-testing Trained passages 4, 5 Untrained passage 6[a] TOWRE-2 SWE, PDE	Ongoing monitoring Untrained passages 2, 5, 8[a] TOWRE-2 SWE, PDE
8		SW RR passage 1	
9		SW RR passage 2	
End wk 9	Ongoing monitoring Trained passages 1, 4 Untrained passage 7[a] TOWRE-2 SWE, PDE	Interim post-testing Trained words: passages 1, 2 Untrained words: passage 3[a] TOWRE-2 SWE, PDE	Ongoing monitoring Untrained passages 1, 4, 7[a] TOWRE-2 SWE, PDE
13	Final post-test Passages A, B, C TOWRE-2 SWE, PDE		Final post-test Passages A, B, C TOWRE-2 SWE, PDE
17	N/A	Final post-test Passages A, B, C TOWRE-2 SWE, PDE	N/A

Note: Passages A, B, C and passages 1 to 8 are from the Wheldall Assessment of Reading Passages (WARP; Wheldall, 1996); SW RR = Repeated reading of single (isolated) words; Passage RR = Repeated reading of passages of connected text; TOWRE-2 SWE, PDE = Test of Word Reading Efficiency – 2nd edition Sight Word Efficiency and Phonemic Decoding Efficiency.
[a]Participants answered six comprehension questions about each of these passages.

Statistical analysis

Data were analysed in three phases. The first phase was conducted to ensure comparability of groups immediately prior to treatment on all variables except fluency. (There was an expectation that the control participants might perform better than the treatment participants on the SWE measure of sight-word reading efficiency, because they had been selected as controls on the basis of having superior SWE scores at entry to the study approximately 2 years earlier.) This first phase of data analysis was achieved through a series of 14, one-way analyses of variance (ANOVAs) with Group as a non-repeated factor (immediate, delayed, control). Standard scores were used as dependant variables for WNV, PPVT, CTOPP-2 memory for digits and PA, RAN, and TOWRE SWE and PDE.

The second phase of data analysis was conducted to examine the effects of RR treatment on the primary dependent variables of reading rate for trained and matched, untrained passages, and sight-word and non-word reading fluency (using the TOWRE-2 SWE and PDE subtests). A series of 3, two-way ANOVAs with non-repeated measures on Group (immediate, delayed, control) and repeated measures on Time (Time 1 = pre-treatment; Time 2 = interim post-testing for the immediate treatment group, extended baseline testing for the delayed group, and ongoing monitoring for the control group [weeks 3 and 5]; Time 3 = interim post-testing for the immediate and delayed treatment groups and ongoing monitoring for the control group [weeks 7 and 9]; Time 4 = post-treatment). Also as part of Phase 2 a follow-up ANOVA to compare single-word with passage RR was performed. This two-way ANOVA was focused on the results for treatment participants only, with non-repeated measures on Group (immediate and delayed) and repeated measures on treatment condition, with four levels (untrained passages pre-treatment; trained passages after single-word RR treatment; trained passages after RR treatment using passages of connected text; untrained passages after treatment). Given the number of analyses conducted in Phase 2, a conservative type I error rate of .01 was adopted.

The third phase in data analysis was to examine generalisation to outcome measures, either fluency-related (NARA-3 rate, accuracy, comprehension; and, RAN) or not (exception word and non-word reading accuracy; orthographic choice, and PA). Raw scores were used to compare pre- versus post-treatment performance, because use of standard scores is not appropriate when assessments are re-administered within 6-12 months of one another. A series of 8 two-way ANOVAs was conducted with non-repeated measures on Group (two levels = treatment [both groups combined] vs. control) and repeated measures on Time (pre- vs. post-treatment). A conservative type I error rate of .006 was adopted to control for multiple comparisons (.05 divided by 8, which was the number of individual ANOVAs conducted).

Results

Participant Characteristics

Prior to treatment, the three participant groups were compared across a range of variables relevant to the study. Mean scores and standard deviations for each measure are presented in Table 2, along with results from a one-way analysis of variance (ANOVA) comparing the children's performance according to treatment group. The groups were closely matched (*p*s > .3) on all variables except for reading rate on the NARA-3, which revealed a small but nonsignificant group difference favouring fluent control participants. As noted earlier, this difference was to be expected in light of our strategy for allocating children to groups, whereby children assigned to the treatment groups were those who entered the study (approx. 2 years earlier) with less fluent single-word reading skills.

Table 2. Participant characteristics at pre-treatment according to treatment group

	Treatment Group			ANOVA results	
Measure	Immediate	Delayed	Control	*F*-value	*p*-value
Age (months)	126.6 (16.9)	122.3 (12.2)	119.0 (16.2)	$F(2,17) = 0.42$	0.661
WNV	99.0 (11.4)	103.3 (16.2)	91.3 (13.9)	$F(2,17) = 1.28$	0.303
PPVT-4	110.7 (7.1)	111.7 (11.4)	116.3 (9.8)	$F(2,17) = 0.68$	0.518
CTOPP-2					
Digit memory	10.9 (3.0)	10.5 (2.7)	9.9 (2.0)	$F(2,17) = 0.27$	0.771
PA (PI)	9.7 (2.1)	9.8 (1.6)	8.4 (1.6)	$F(2,17) = 1.30$	0.300
RAN Digits	106.4 (10.1)	106.0 (15.9)	111.9 (11.8)	$F(2,17) = 0.45$	0.644
C&L					
Exceptions	24.4 (1.7)	23.7 (3.0)	23.7 (2.7)	$F(2,17) = 0.20$	0.823
Nonwords	27.3 (2.5)	26.0 (3.2)	25.1 (5.5)	$F(2,17) = 0.52$	0.604
ORTH. CHOICE	43.3 (4.4)	45.0 (6.0)	46.3 (4.5)	$F(2,17) = 0.64$	0.539
NARA-3					
Accuracy	71.0 (11.5)	68.3 (11.5)	70.9 (20.3)	$F(2,17) = 0.06$	0.941
Rate	97.4 (21.3)	102.3 (28.3)	128.3 (28.6)	$F(2,17) = 2.78$[a]	0.090
Comprehension	26.1 (7.3)	24.3 (3.7)	24.1 (11.0)	$F(2,17) = 0.13$	0.881
TOWRE-2					
SWE	102.0 (8.8)	105.3 (9.8)	107.9 (8.5)	$F(2, 17) = 0.74$	0.490
PDE	101.1 (9.8)	104.2 (9.7)	109.1 (10.1)	$F(2,17) = 1.17$	0.335

Note: WNV = Wechsler non-verbal full scale IQ scores; PPVT-4 = Peabody Picture Vocabulary Test 4th edition standard score; CTOPP-2 = Comprehensive Test of Phonological Processing 2nd edition; Digit memory = CTOPP-2 digit memory standard score; PA (PI) = CTOPP-2 Phoneme isolation subtest standard score; RAN Digits = Rapid Automatised Naming of digits standard score; C&L = Coltheart and Leahy reading test (1996); Exceptions = C&L exception word raw score (no. correct out of 30); Nonwords = C&L non-word raw score (no. correct out of 30); Orth. Choice = Olson et al.'s Orthographic Choice Task raw score (no. correct out of 52); NARA-3 = Neale (1999); Accuracy = NARA-3 raw score; Rate = NARA-3 raw score (wpm); Comprehension = NARA-3 raw score (no. correct out of 44); TOWRE-2 = Test of Word Reading Efficiency – Second Edition;

SWE = TOWRE-2 sight-word efficiency standard score; PDE = TOWRE-2 phonemic decoding efficiency standard score.

Also, evident from the results in Table 2 is that all groups of participants performed within or slightly above the typical range (*Mean* +/- 1*SD*) on measures for which standard scores are reported; in particular, nonverbal cognitive ability, receptive vocabulary, digit memory, PA, RAN (for digits), and sight-word and phonemic decoding efficiency (SWE and PDE).

Effects of RR on reading rate of trained and/or matched, untrained passages

The first research question was whether RR would be effective in improving reading rate of trained and/or matched, untrained passages. Before reporting the main data, however, it is worth noting that the three participant groups performed similarly well in answering comprehension questions about untrained passages during the treatment period (in weeks 3, 5, 7, and 9). The immediate treatment group achieved a mean score of 5.4 (out of 6), compared to 5.6 for the delayed group and 5.2 for the control group, revealing a non-significant difference between the groups ($F[2,17] = 1.32$, $p = .295$), and suggesting that participants were, in fact, reading for comprehension.

Table 3 presents the mean reading rate (in wcpm) on WARP passages, for each of the three participant groups in each phase of the experiment. The results are consistent with our first hypothesis, in showing a different pattern of improvement across time in the three treatment groups, as reflected in a significant interaction $F(6,51) = 7.296$, $p < .001$). The effect of time was significant in the immediate and delayed treatment groups, with $F(3,18) = 39.93$, $p < .001$ and ($F(3,15) = 10.49$, $p = .001$, respectively; but there was no significant change in reading rate across time for the no-treatment control group, with $F(3,18) = 2.856$, $p = .066$. More specifically, reading rate in the two treatment groups improved significantly after treatment. Thus, for the immediate treatment group, rates improved significantly from time 1 to time 2, with $F(1,6) = 60.51$, $p < .001$; whereas for the delayed treatment group, rates were similar at times 1 and 2 ($F < 1$), but improved significantly from time 1 to time 3, with $F(1,5) = 44.01$, $p = .001$. When data from the two treatment groups were combined, the comparison between pre- and post-treatment reading rate was also significant, with $F(1,12) = 21.60$, $p < .001$.

Table 3. Reading rate (words correct per minute) on WARP passages pre-, during, and post-treatment according to group

Group	Time 1 Pre-Treat	Time 2 Interim Post (1) Ext B/L (2)	Time 3 Interim Post	Time 4 Post-Treat
Treatment				
1. Immediate	146.5 (26.7)	**181.0 (33.9)**	**195.8 (34.0)**	**172.6 (37.8)**
2. Delayed	161.6 (40.8)	158.8 (42.9)	**204.2 (39.3)**	**187.4 (62.7)**
Control	187.2 (45.7)	182.8 (33.9)	196.0 (36.9)	196.2 (46.7)

Note: Figures in bold font are **post-treatment**; Interim Post (1) = first interim post-testing results for immediate treatment group (weeks 3 and 5); Ext B/L (2) = extended baseline testing results for delayed treatment group (weeks 3 and 5); Interim Post = interim post-testing results for both treatment groups (weeks 7 and 9).

RR of single-words versus passages of connected text

The second research question was whether the effects of RR would differ according to the nature of training materials used; in particular, whether RR of single words or passages of connected text would be more effective in improving reading rate. Data to address this question came from treatment groups only. Table 4 shows the mean reading rates of the two treatment groups for passages of text in four conditions: untrained passages *before* treatment (pre-treatment), single-word trained passages containing constituent words that were read in list format during treatment; text-trained passages that were read as connected text during treatment; and untrained passages *after* treatment. The results show a significant difference in reading rate across the four conditions, with $F(3,33) = 48.55$, $p < .001$, but no main effect of group ($F[1,11] = 1.15$, $p = .306$) and no interaction between group and treatment ($F < 1$); that is, the effect of treatment was similar regardless of whether it was received immediately in the order single-words followed by passages, or it was received after an extended baseline period in the order passages followed by single words.

The main effect of condition was subjected to more detailed analysis collapsing across the two treatment groups. Pre-treatment reading rates were significantly slower than all three post-treatment rates. Contrasts revealed a significant difference between reading rates on untrained passages *before* treatment and those recorded *after* treatment on single-word trained passages ($F[1,11] = 26.09$, $p < .001$), text-trained passages ($F[1,11] = 75.33$, $p < .001$), and untrained passages ($F[1,11] = 12.463$, $p = .005$). In addition, there was a significant difference in reading rates that favoured text-trained over single-word trained passages, with $F(1,11) = 55.54$, $p < .001$.

Table 4. Reading rates (wcpm) according to treatment group and the nature of RR stimulus materials (single-words vs. passages of connected text)

Group	Pre-Treat	Single-word-trained passages	Text-trained passages	Untrained passages
Immediate Treatment	146.5 (26.7)	152.5 (28.8)	235.4 (44.3)	155.3 (30.4)
Delayed Treatment	161.6 (40.8)	180.4 (43.3)	246.3 (37.8)	185.8 (58.5)

Note: Pre-Treat = Pre-testing prior to treatment

Effects of RR on measures of untrained single-word and non-word reading fluency

To investigate the third research question, regarding the influence of RR on sight-word and non-word reading fluency, parallel forms of the TOWRE-2 measures of SWE and PDE were administered on a regular basis before, during, and after RR. The mean raw scores (number of items read correctly in a 45-second period) are presented in Table 5. Although both of these measures show evidence of improvement in children's reading fluency across the course of the study, with $F(3,51) = 10.82$, $p < .001$ for SWE and $F(3,51) = 10.44$, $p < .001$ for PDE, there is no evidence that these improvements were brought about by RR treatment. In both cases, the interaction between group and time was non-significant, with $F(6,51) = 1.09$, $p = .384$ for SWE and $F(6,51) = 1.65$, $p = .152$ for PDE.

Table 5. Mean raw scores (number correct) and SDs for sight-words (SWE) and nonwords (PDE) on the TOWRE-2 before, during, and after treatment, according to group

Group	Time 1 Pre-Treat	Time 2 Interim Post (1) Ext B/L (2)	Time 3 Interim Post	Time 4 Post-Treat
		Sight Word Efficiency (SWE)		
Immediate Treatment	72.1 (3.2)	**71.9 (3.6)**	**77.9 (3.3)**	**78.3 (3.2)**
Delayed Treatment	71.5 (3.4)	71.2 (3.9)	**76.5 (3.6)**	**75.3 (3.5)**
Control	73.3 (3.2)	75.7 (3.6)	77.1 (3.3)	76.3 (3.2)
		Phonemic Decoding Efficiency (PDE)		
Immediate Treatment	38.0 (3.7)	**39.5 (3.8)**	**43.4 (3.6)**	**43.7 (3.3)**
Delayed Treatment	39.3 (4.0)	39.1 (4.1)	**40.8 (3.9)**	**45.2 (3.6)**
Control	40.6 (3.7)	42.6 (3.8)	43.6 (3.6)	43.1 (3.3)

Note: Figures in bold font are post-treatment; Interim Post (1) = first interim post-testing results for immediate treatment group (weeks 3 and 5); Ext B/L (2) = extended baseline testing results for delayed treatment group (weeks 3 and 5); Interim Post = interim post-testing results for both treatment groups (weeks 7 and 9).

Effects of RR on passage comprehension, RAN, word and non-word reading accuracy, and PA

The fourth and final research question was whether RR would be effective for improving passage comprehension, RAN (for digits), word and non-word reading accuracy, or PA. Table 6 summarises *mean* raw scores and *SD*s for pre- and post- treatment measures of these reading and related outcomes according to group (combined treatment vs. no-treatment controls).

Table 6. Outcomes (*mean* raw scores and *SD*s) for passage reading rate, accuracy and comprehension on the NARA-3, oral reading accuracy, RAN, and PA at pre- and post-treatment according to group (combined treatment vs. no-treatment control)

	Group			
	Treatment (n = 13)		Control (n = 7)	
	Time			
Outcome measure	Pre	Post	Pre	Post
NARA-3				
Rate	99.7 (23.8)	104.9 (27.9)	128.3 (28.6)	123.9 (25.7)
Accuracy	69.8 (11.1)	78.5 (11.6)	70.9 (20.3)	72.7 (19.2)
Comprehension	25.3 (5.8)	31.2 (6.4)	24.1 (11.0)	27.4 (8.6)
C&L				
Exception words	24.1 (2.3)	24.6 (2.5)	23.7 (2.7)	24.3 (2.5)
Nonwords	26.7 (2.8)	29.1 (1.1)	25.1 (5.5)	25.7 (6.4)
ORTH. CHOICE	44.1 (5.1)	45.2 (3.5)	46.3 (4.5)	46.4 (3.0)
RAN Digits	25.5 (7.6)	24.2 (5.9)	24.4 (7.1)	25.1 (9.0)
CTOPP-2: PA				
Phoneme isolation	26.5 (2.3)	28.2 (1.0)	24.3 (3.8)	26.1 (2.0)

Note: NARA-3 = Neale Analysis of Reading Ability – 3rd edition; C&L = Coltheart and Leahy (1996) oral reading test; ORTH. CHOICE = Olson et al. (1989) Orthographic choice task; RAN Digits = Rapid Automatised Naming of digits; CTOPP-2: PA = Comprehensive Test of Phonological Processing - 2nd edition: Phonological Awareness.
$p \leq .006$ required for significance (.05 divided by 8)

The results provide evidence of significant improvement in two of the measured skills over the course of the treatment period. In particular, the improvement in non-word reading accuracy on the Coltheart and Leahy (1996) was significant, with $F(1,18) = 11.05$, $p = .004$, as was the improvement in passage comprehension on the NARA-3, with $F(1,18) = 13.85$, $p = .002$. In neither case, however, did the interaction with group approach significance – $F(1,18) = 4.16$, $p = .056$ for non-word reading accuracy, and $F(1,18) = 1.09$, $p = .311$ for passage comprehension. As such, the results provide little evidence for an effect of RR treatment on these variables; and no other comparisons reached significance using our corrected *p*-value of .006.

Discussion

The primary aim of this study was to evaluate the effectiveness of RR for a group of mixed-ability students (in primary grades 3-6) who displayed accurate single-word decoding skills. To address this aim, children were divided into three groups: two treatment groups, one immediate and one delayed took part in RR, while a third, control group received no treatment, but was assessed on the same measures and according to the same schedule as the treatment participants (i.e., fortnightly monitoring).

Prior to the commencement of treatment, the three groups of participants were compared across a range of measures relevant to reading development (i.e., accuracy and fluency) and background variables (e.g., non-verbal cognitive ability and receptive vocabulary). The three groups performed similarly on all measures except for reading rate on the NARA-3 passage reading comprehension test, which showed a small but nonsignificant group difference in favour of the control group. This difference was to be expected given that children were allocated to treatment or control groups according to their single-word reading fluency as measured approximately 2 years earlier (i.e., children with a history of less fluent reading were assigned to the treatment group, whereas children with a history of more fluent reading were assigned to the control group). Four research questions were addressed. First, is RR effective in improving reading rate of trained and/or matched, untrained passages? Second, if RR is effective, do its effects differ as a function of training materials used (single-words vs. connected text)? Third, do effects of RR generalise to measures of untrained single-word and non-word reading fluency? And finally, do effects of RR generalise to a popular measure of passage reading comprehension (NARA-3), RAN, single-word and non-word reading accuracy, or PA?

Effects of RR on reading fluency

In regard to the first research question, the findings confirmed our hypothesis that children with average reading fluency and adequate single-word decoding skills would show improved passage reading fluency after receiving weekly treatment in the form of RR. Immediate gains in reading rate (wcpm) were evident on both trained and matched, untrained passages, during and after treatment. Importantly, similar results were not apparent for the "no treatment" control group. These results are consistent with those from previous studies, which showed that RR was an effective instructional practice for the remediation of reading fluency deficits (e.g., Meyer & Felton, 1999; Rashotte & Torgesen, 1985; Samuels, 2006).

An additional focus of this study, addressed in the second research question, was whether the materials used for training (single-words or passages of connected text) would affect the strength of immediate gains (on trained and/or matched, untrained passages). Our results demonstrated, similar to other studies, that reading rate improved significantly from pre-to post-treatment irrespective of the training materials used; that is, single-words or passages of connected text (e.g., Ring et al., 2013; Torgesen & Hudson, 2006). More specifically, significant treatment effects were evident on reading rates for passages whose constituent words were trained, and passages that were trained in their entirety (as connected text). Moreover, treatment effects generalised to matched, untrained passages, which were read more quickly after RR (of single-words and passages) than before. In this regard, the current results resemble those of Levy et al. (1997) in showing that training all content words from a target passage resulted in improved reading fluency for those words when presented in context. A potentially important point of difference between the current study and that of Levy et al, however, lies in our training of *all* constituent words, including both content and function words. Using this methodology maximised the similarity in content between single-word and passage-level RR in the current study, and thereby enabled a more direct comparison between the two RR conditions.

Notwithstanding the effectiveness of single-word RR as illustrated here, the current results also show, in accordance with previous studies, that RR for passages was more effective for improving passage reading fluency than RR for single-words (Faulkner & Levy, 1994; Martin-Chang & Levy, 2005; Rashotte & Torgesen, 1985; Therrien & Kubina, 2007). Moreover, this pattern of results was found despite our use of all constituent words, including function words, in the single-word RR condition. In accounting for a similar finding, Martin-Chang and Levy proposed that reading words in context might result in more efficient single-word recognition through the establishment of stronger lexical representations as a result of the increased involvement of semantic processes. While Martin-Chang and Levy's findings did not extend to unfamiliar passages the results of our study did, suggesting that if their interpretation is correct, the increased semantic involvement which occurs as a result of training passages comes not simply from the meaning of the trained passage itself, but also from potential semantic implications and associations to words and ideas that are only *indirectly* linked to the meaning of the trained passage *per se*.

In summary, our findings support the view that RR is effective in improving children's reading fluency, especially when passages of connected text are used for training purposes. As yet, however, we have not considered the question of whether the beneficial effects of RR generalise to reading materials that less closely resemble those used for training. One way of addressing this issue in the current study was to seek evidence of generalisation to measures of untrained sight-word and non-word reading fluency. In line with this aim, alternate forms of the TOWRE-2 SWE and PDE subtests were administered before, during and after treatment. Consistent with findings reported by Ring et al. (2013) the results showed no significant benefit of RR training for improving sight-word or non-word reading fluency. Thus, although both SWE and PDE showed evidence of significant improvement over the course of the treatment period, there was no indication that the observed improvement was due to RR, because it was equally apparent in both treatment and control participants (an issue to which we return below). Further evidence of generalisation was sought using measures of passage reading comprehension, RAN (for digits), word and non-word reading accuracy, and PA.

In accordance with findings reported previously in the literature (e.g., Fleisher et al., 1979; Martin-Chang & Levy, 2005; Rashotte & Torgesen, 1985), RR did not appear to be associated with improvements in children's passage reading comprehension post-treatment, at least in terms of performance on the NARA-3 passage reading test. Various factors may have contributed to this null finding. First, if a child's inability to understand what they read is attributable to poor reading fluency (Jenkins et al., 2003; Levy et al., 1997), we would expect an improvement in comprehension to follow RR in situations where reading fluency also improved. In the current study, however, beneficial effects of RR did not generalise to reading rate or accuracy on the NARA-3; and a measure of comprehension for trained and matched, untrained passages from the WARP, which did show evidence of improvement, was not included in pre- and post-assessment test batteries. A second relevant issue relates to the finding that all children, including those in the control group, demonstrated better reading comprehension abilities post-treatment. This finding is discussed in greater detail below, but for now we note that an unexplained improvement in the reading behaviour of children who did not take part in RR training complicates interpretation of the improvements that were evident for treatment children.

Before moving on to consider the progress made by children in both treatment and control groups, a final aspect of the current results deserves mention. In accordance with previous research, we hypothesised that RR would lead to better RAN performance as a result of improvements in reading fluency and associated orthographic processes (Bowers, 1993; Wolff, 2014). However, we found no effects of RR treatment on RAN performance; our results confirming those of other researchers that although students may exhibit improved reading skills following RR, those improvements do not necessarily generalise to rapid naming (e.g., Kirby et al., 2010). It is possible that children's above average performance on RAN prior to treatment (see Table 2) and/or the short (4-week) period of RR training might both have contributed to the failure to find a significant improvement in RAN.

Interpretation of overall improvements

As mentioned above, results of the current study provided evidence of some unexpected gains from pre-to post-treatment. Specifically, both treatment and control participants improved significantly in passage reading comprehension (NARA-3), and in reading accuracy for nonwords on the Coltheart and Leahy (1996) oral reading assessment. Because these improvements were observed in control children as well as those who received RR treatment, they cannot be explained by RR.

Although some studies have reported improved passage comprehension, associated with improved reading rate (Jenkins et al., 2003; Levy et al., 1997), the current results do not show evidence of such an association. There was no significant change in reading accuracy or reading rate on the NARA-3 over the course of the study. As such, improved performance in comprehension cannot be attributed to increased reading fluency. Other studies have reported similar gains in comprehension but usually as a result of additional training in meaning-making strategies (e.g., Therrien & Hughes, 2008; Therrien et al., 2006). Again, this explanation cannot be applied in the current study, because no specific training of comprehension was provided for either treatment or control children.

Also unexpected was the significant overall improvement in non-word reading accuracy on the Coltheart and Leahy (1996) test of oral reading. Together with the significant improvements already described on both SWE and PDE over the course of the study, these changes in both treatment and control participants are difficult to explain. We propose, however, that they, and the observed improvements in comprehension, may result partly from the increased time spent on reading as a result of children's participation in the study. In this context, it is important to note that even control participants were engaged in extra reading practice over the course of the study, due to the ongoing monitoring of their reading on a fortnightly basis. This possible explanation is consistent with evidence suggesting that promoting engaged reading time can lead to improved reading performance (Cunningham & Stanovich, 1998; Guthrie, Schafer & Huang, 2001; Morgan & Fuchs, 2007).

Regardless of how we account for the observed overall improvements in children's reading performance over the course of the current study, it is important to note that not all findings can be attributed solely to increased reading time (as suggested by Kuhn & Stahl, 2003). On the contrary, findings for reading rate of trained and matched, untrained passages show clear and significant effects of RR, with no change in the performance of untreated control participants.

Strengths, Limitations and future directions

A possible limitation of this study lies in the length of the treatment period. Students in the two treatment groups received a total of 12 RR sessions (3 per week for 4 weeks), during which time reading rate improved significantly on trained and matched, untrained passages; however, this short period of training may not have been sufficient to observe generalisation to a passage reading test (the NARA-3) which less closely resembled the training materials. A question for future investigation is whether the beneficial effects of RR would generalise to completely different measures of reading as a result of a longer treatment period (e.g., 50 sessions over 4 months, as per Therrien et al., 2006). In addition, Therrien et al. concluded that improvements could be enhanced through inclusion of a performance criterion (e.g., a pre-established number of words correct per minute) rather than a required number of readings. Future research should replicate the current study over a longer period and with the addition of a performance criterion.

Another issue worthy of further investigation is the extent to which the performance of control participants might be influenced simply by the extra reading time in which they engage as a result of ongoing assessment. In a follow-up study, it would be interesting to include an additional group of control participants who do not complete all of the monitoring assessments (see Table 1) but only the pre- and post-tests to investigate the effect on their pre- to post-testing results.

Additional studies might also consider examining whether RR treatments that involve training of single-words and/or passages are more effective at various stages of reading development, as this knowledge would facilitate teachers' planning of more targeted instruction at particular stages of reading development.

Practical implications for classroom teachers

RR intervention is commonly used in Australian classrooms. As such, the findings of this study provide important information for classroom teachers and practitioners alike, regarding the benefits of this approach to enhance reading fluency in children of primary-school-age. The current findings support those of previous research, suggesting that the immediate gains achieved by readers *after only a small number of treatment sessions* warrant the inclusion of RR into classroom instruction of reading. They further support the inclusion of oral reading practice as an additional strategy for promoting fluency, with evidence suggesting that RR is easily combined with existing reading programs (O'Connor et al. 2007; Therrien & Kubina, 2006).

The results of this study furthermore suggest that classroom reading instruction programs should include RR of words in isolation or in context either can provide immediate gains in reading rate. This information is important for educators and researchers, because the efficacy of RR intervention relies on suitable choice of materials for re-reading (e.g., Therrien & Kubina, 2006). In particular, for younger students at the early stages of reading acquisition or for those experiencing difficulty in learning to read, practice that involves re-reading single-words may help build orthographic knowledge (ability to quickly and accurately recognise letter patterns in words), and thus later passage reading fluency (Barker et al., 1992). For older or more proficient readers, re-reading passages of connected text might assist in developing automatic word reading and also assist in identifying and using syntactic clues crucial for effortless, prosodic reading (Hudson et al. 2005).

Conclusion

It is essential that classroom instruction of reading includes all skills associated with reading development, in order to move students beyond being only *accurate* readers but also *fluent* readers. The importance of creating skilled, independent readers cannot be underestimated, as such ability impacts participation in classroom learning opportunities, and later employment and social opportunities. RR is a popular and successful strategy used to promote reading fluency by promoting increased oral reading practice. Furthermore, it can be easily implemented in a classroom of mixed-ability students. Regardless of the limitations of the current study, the results support those of other researchers, which suggest that RR is effective for improving fluency on both passages that are re-read and those that are untrained. Although treatment containing either single-words or passages improves reading fluency, training words in connected text seems to achieve greater improvements in reading. Finally, reading comprehension, might be improved by RR instruction, however the inconclusive results reported here and in the literature suggest that further investigation of this aspect is necessary.

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CHAPTER FIVE

DISCUSSION

The aims of this investigation were, first, to examine the utility of the RAN task for identifying students in need of further detailed assessment and targeted reading instruction; and second, to investigate the efficacy of Repeated Reading (RR) intervention (using single-words and passages) in children with average or below reading fluency. The investigation was conducted in two phases with findings presented in a series of three papers.

The study reported in Paper 1 (Chapter 2) investigated the degree to which the strength of the association between RAN and reading varies according to the nature of the RAN task and the particular aspect of reading ability under consideration in a sample of mixed-ability readers from grades 2 to 4. Of particular interest was whether the RAN-reading relationship varies according to the stimuli to be named and the direction of scanning required in the RAN task; and whether all reading measures would show a similar pattern of results.

The second paper (reported in Chapter 3) extended the issue of timely and appropriate assessment, by investigating the utility of the RAN task as a potential screener for profiling reading difficulties in children from grades 2 to 4. Children were divided into four reader subtypes according to their performances on a RAN digit task and a measure of PA. A particular focus was whether the RAN task would be useful for identifying those children who had poor reading fluency or were at risk of developing poor reading fluency.

Finally, the study reported in Paper 3 (Chapter 4), evaluated the effectiveness of RR instruction (using single-words and passages) for a group of primary-school-aged children of mixed-ability who displayed accurate single-word decoding skills and average or below average single-word reading fluency. As part of the study, children were divided into three groups: two treatment groups, one immediate and one delayed took part in RR, while a third, control group received no treatment, but was assessed on the same measures and according to the same schedule as the treatment participants. Previous research showed that the success of

RR instruction relies on suitable choice of materials for re-reading and effective administration procedures. Such information is therefore crucial for classroom teachers and other reading practitioners in assisting them to design effective instructional programs. Consequently, the focus of this research explored whether the materials used for training (single words or passages of connected text) would affect the strength of immediate gains (on trained passages) and or transfer effects (generalisation to untrained passages).

The utility of RAN

The nature of the RAN task

With respect to whether the RAN-reading relationship differs as a function of the stimuli to be named or the direction of scanning required, the current findings are consistent with earlier studies, showing that beyond kindergarten non-alphanumeric stimuli were less useful as predictors of reading ability (e.g., Clarke, Hulme & Snowling, 2005; Misra, Katzir, Wolf & Poldrack, 2004). The current results are therefore consistent with the view that, for children in this age group (grades 2-4), the association between RAN and reading depends on the use of highly familiar stimuli for naming (Norton & Wolf, 2012). The results are also in line with the DDH (Wolf & Bowers, 1999), in that alphanumeric RAN was significantly associated with reading after controlling for variation in age, letter knowledge, and, PA.

Despite the agreement between the current results and those reported previously in the literature, some points of difference are also apparent; for example, Papadopoulos, Spanoudis and Georgiou (2016) reported that both non-alphanumeric and alphanumeric RAN predicted oral reading fluency in grades 1 and 2; and Kruk, Mayar and Funk (2014) found that non-alphanumeric RAN (assessed in grade 1) accounted for significant unique variance in exception word reading in grade 2. An explanation for these different patterns of results could lie in the use of younger participants (grades 1-2) in these previous studies compared to the older children who took part in the current study (i.e., grades 2-4).

Another difference between the current results and those of some previous research relates to the comparative strength of the association between reading and RAN depending on the use of letters or digits for naming. Whereas Clarke et al. (2005) found that, after controlling for variation in PA, RAN-digits was a stronger predictor of exception-word reading accuracy than RAN for letters, Abu-Hamour, Urso and Mather (2012) and Neuhaus, Foorman, Francis and Carlson (2001) both reported a stronger association between RAN-letters and reading. The current findings fell somewhere in between these views, revealing no consistent difference between letters and digits. Although the reasons for this difference between studies is not clear, the use of RAN- digits may provide a truer reflection of the association between reading and RAN per se, because digits are not part of the alphabetic system.

The results of the current investigation also confirm those of previous research in that the RAN-reading link varied as a function of the reading measure used. Well documented in the literature and supported by the current study is the association between RAN and orthographic processing (exception word reading and/or orthographic choice; e.g., Clarke et al., 2005; Manis, Doi & Bhadha, 2000), and the link between RAN and reading fluency (e.g., Bowers, 1993; Savage & Frederickson, 2005). Once again, however, the current results also differ from some previous research that has reported a somewhat stronger associations between RAN and non-word reading than between RAN and exception word reading (Abu-Hamour et al., 2012), and an association with oral but not silent reading (Papadopoulos et al., 2016). These differences most likely reflect the measures used in the various studies. Abu-Hamour et al. used a *timed* non-word reading measure, which undoubtedly increased the likelihood of their finding a positive association with RAN; and Papadopolous et al. used a silent reading task in which children were required to identify the word boundaries from within a continuous line of print. The very different nature of the silent reading task used in the current research, in which participants were required to read passages of text for understanding, could well have contributed to the observed differences.

Additionally, although some previous research has shown a significant association between RAN and passage reading comprehension (e.g., Neuhaus et al., 2001) or RAN and passage reading accuracy (e.g., Savage & Frederickson, 2005), the current investigation provides little supporting evidence. Once again, methodological differences between studies might be responsible for the variation in findings. Thus, by contrast with Neuhaus et al., partial correlations were used in the current study to control for variation in PA; and, unlike Savage and Frederickson, whose participants were older children with a prior diagnosis of dyslexia, the current participants were of mixed-ability in grades 2 and 4.

Finally, in terms of the direction of scanning required in the RAN task, a commonly-held view in the literature is that the RAN-reading association is observed because both tasks involve serial *left-to-right* scanning (e.g., Abu-Hamour et al., 2012; Norton & Wolf, 2012). The results from this investigation, however, showed little effect of scanning direction (horizontal vs. vertical). Since no previous studies have focused on serial, vertical RAN, comparisons with previous literature are limited. Nevertheless, Protopapas, Altani and Georgiou (2013), found that RAN-backwards also had a strong link to reading suggesting, in line with the current investigation that changing the direction of scanning is not detrimental to RAN's association with reading.

In sum, the findings reported here have important implications for interpreting the RAN-reading link. After controlling for age, letter knowledge and PA, alphanumeric RAN is strongly related to measures of single exception-word reading; orthographic choice; word and non-word fluency; and passage-reading rate, both oral and silent, all of which are essential skills for fluent reading (e.g., Bowers, 1993; Clarke et al., 2005; Savage & Frederickson, 2005). A strength of the investigation in comparison to previous studies lies in the inclusion of a wide range of RAN stimuli (objects, colours, letters, digits) rather than just one or two, to establish a correlation with a wide variety of reading skills.

RAN and reader subtyping

In terms of the utility of RAN as a screener for identifying potential reading difficulties in early-primary-aged children the current results show that children with below average RAN were significantly less accurate in oral reading of exception words than children with average or above average RAN, regardless of having similar levels of PA (see Paper 2). In addition, the RAN groups differed significantly in single-word and non-word reading fluency, and in all aspects of passage reading (accuracy, rate, and comprehension). By contrast, when children with below average PA were compared to children with average or above average PA, group differences were evident, not in exception word reading accuracy or passage reading rate, but rather in non-word reading accuracy. These results confirm others in the literature, which indicate that poor performance on measures of RAN is an additional, independent indicator of current and/or future reading fluency difficulties in children (e.g., Denckla & Rudel, 1976; Norton & Wolf, 2012; Wolf & Bowers, 1999).

From a theoretical perspective, the current study is consistent with the DDH (Wolf & Bowers, 1999), in showing that early readers can have singular deficits in either PA or RAN, or a “double deficit” in both, with this latter group being the most impaired of all in terms of reading fluency. From a practical perspective, this investigation revealed that approximately 12% of students (7 out of 58) were identified as having a deficit in RAN only; had the RAN task not been included along with PA for subtyping purposes, these children would have been mistakenly classified as good readers. As such, the current findings reinforce claims in the literature in terms of the potential benefits of including the RAN task in a battery of diagnostic assessments designed to profile readers in a way that would assist in planning appropriate instruction or intervention strategies. Conversely, failure to do so could result in misdiagnosis and/or mistreatment of developing readers (Meisinger, Bloom & Hynd, 2010).

Efficacy of RR intervention

The final results from this investigation of children's reading fluency show that children with average reading fluency and adequate single-word decoding skills improved their passage reading fluency after receiving weekly treatment in the form of RR, with immediate gains in reading rate (wcpm) evident on both trained and matched, untrained passages. Similar gains were not found for a control group of participants who received no treatment, but were assessed according to the same fortnightly schedule. The findings of this investigation are consistent with those from previous studies in providing evidence that RR is an effective instructional practice for the remediation of reading fluency deficits (e.g. Meyer & Felton, 1999; Rashotte & Torgesen, 1985; Samuels, 2006). Similar to other studies, reading rate improved significantly from pre-to post-treatment irrespective of whether single-words or passages of connected text were used for training purposes (e.g. Ring, Barefoot, Avrit, Brown & Black, 2013; Torgesen & Hudson, 2006).

The results resemble those of Levy, Abello and Lysynchuk (1997) in showing that training all content words from a target passage resulted in improved reading fluency for those words when presented subsequently in context; however, an important difference in the current investigation was that the training included all constituent words, both content and function words. In adopting this methodology, the similarity in content between single-word and passage-level RR was maximised in the current study, and as a result enabled a more direct comparison between the two RR conditions. Despite ensuring identical content in this way, RR for passages of connected text remained more effective than single-word RR in bringing about an improvement in passage-reading fluency, a pattern that was also reported in previous research (e.g., Faulkner & Levy, 1999; Martin-Chang & Levy, 2005; Rashotte & Torgesen, 1985; Therrien & Kubina, 2007).

Also consistent with some previous findings the effects of RR did not generalise to other reading or reading-related measures (Fleisher, Jenkins & Pany, 1979; Martin-Chang & Levy, 2005; Rashotte & Torgesen, 1985; Ring et al., 2013), despite the fact that children in both treatment and control groups showed evidence of improvement over the course of the study in single-word and non-word reading fluency, passage comprehension, and non-word reading accuracy. Moreover, unlike the findings of Bowers (1993) and Wolff (2014) RR did not result in better RAN performances, perhaps because children had average to good RAN prior to treatment. In a more general sense, the short (4-week) period of RR treatment, might not have been sufficient to enable generalisation effects to other reading measures (e.g. Therrien, Wickstrom & Jones, 2006).

While further investigation is needed into which components of RR provide the greatest generalisation effects, current findings add to the literature to date, which suggests that RR is suitable for inclusion in a classroom reading instruction program.

Practical implications

The findings from this investigation have important practical implications for classroom teachers and learning support practitioners. They demonstrate that if ongoing assessments do not include all relevant aspects of reading and reading-related skills, some children’s difficulties may remain undetected, and result in their not receiving intervention, or their showing little improvement in reading outcomes despite intervention (Meisinger et al., 2010). Importantly, this investigation helps to address the question as to which assessment strategies will prove most useful for planning targeted instruction, particularly for those students whose reading might not yet extend to passages of text.

Consistent with previous findings, results of this investigation support the use of the RAN task as a valuable screener for identifying fluency deficits in children in the early stages of reading development (e.g., Bowers & Swanson, 1991; Denckla & Rudel, 1976; Georgiou, Parrila, Manolitsis & Kirby, 2011; Norton & Wolf, 2012). The RAN task is currently underutilised in Australian classrooms, despite its ease of administration. The current findings address this problem by providing a clear explanation of specific associations between alphanumeric RAN tasks and different measures of reading; and in doing so provide support for the view that in addition to PA, RAN could be an effective diagnostic assessment of children's current and/or future reading abilities (e.g., Katzir et al., 2006). Results from this investigation indicate that without assessing for rapid naming a child's profile of strengths and weaknesses may fail to indicate either the presence of a reading difficulty or its nature. The significance of being able to identify children with selective deficits is the ability to then form subtypes of readers with particular profiles of reading strengths and weaknesses. This process is particularly important for the design and delivery of appropriate instruction and intervention. For example, those children displaying deficits in RAN would most likely benefit from interventions that explicitly train automaticity (e.g., RR); those with single PA deficits would be more likely to benefit from explicit, systematic training in PA and/or nonword decoding; and those with a double-deficit would benefit from a combination of instructional approaches.

Furthermore, the results of this investigation confirm the benefits of RR for enhancing reading fluency in children of primary-school-age. The current findings support those of previous research, suggesting that the immediate gains achieved by readers *after only a small number of treatment sessions* warrant the inclusion of RR (using single-words and/or passages) into classroom instruction of reading. They further support the inclusion of oral reading practice as an additional strategy for promoting fluency, with evidence suggesting that RR is easily combined with existing reading programs (O'Connor, White & Swanson, 2007; Therrien & Kubina, 2006).

Limitations and future research

A possible limitation of the first phase of this investigation lies in the homogeneous nature of the participant sample. All children came from a medium socio-economic, Anglo-Saxon area with caregivers generally being well-educated (most having 13+ years of education). Although inclusion of such a homogeneous sample has the advantage of reducing variability between participants, it also means that the sample does not reflect wider school populations. Future research should replicate the findings in a larger sample containing a more diverse school population in terms of ethnicity and socio-economics.

Another possible limitation is the high number of children in our original sample of 74 with low nonverbal ability (NVIQ < 80). Although it is unclear why more children than expected scored below 80 on the WNV (i.e. just over 20% compared to an expected rate of 10%), it is reassuring that scores achieved by the included participants were, on average, as expected.

An additional limitation relating specifically to the RR study lies in the length of the treatment period, which encompassed just 12 RR sessions. An extended replication of this study may consider a longer treatment period, which may have beneficial effects in generalising to completely different measures of reading as a result.

Finally, subsequent studies might also consider examining whether RR treatments that involve training of single-words and/or passages are more effective at different stages of reading development, as this knowledge would facilitate teachers' and others practitioners' planning of more targeted instruction at particular stages of reading development. Particularly for younger students first learning to read, or for students experiencing difficulty with learning, the establishment of efficient word recognition skills is essential. Therefore, practice in re-reading single-words may help these children to quickly and accurately recognise letter patterns in words, and thereby lead to improvement in passage reading fluency. For older or more accomplished readers, re-reading passages might assist in building expressiveness using knowledge of syntactic clues essential for effortless, prosodic reading (Hudson, Lane & Pullen, 2005).

Conclusion

The findings reported in this investigation extend the literature examining children's reading fluency, in an effort to ensure that the assessments we use to diagnose reading difficulties in early primary-school-aged children incorporate all aspects of reading, including fluency. This study adds weight to previous research showing that alphanumeric RAN is an important correlate of early reading independent of PA and letter knowledge, and therefore would be a valuable addition to a diagnostic assessment battery. In particular, RAN performance can provide information regarding orthographic processing efficiency as reflected in exception-word reading accuracy, and word and passage reading rate, which are essential skills for fluent reading. The significance of teachers and other reading practitioners understanding why some children achieve fluency while others do not cannot be overstated. Such understanding will ultimately influence practitioners' ability to plan effective assessment, quality instruction, and targeted intervention as necessary. It is essential that classroom instruction of reading and clinical intervention for reading difficulties includes all skills associated with reading development, in order to ensure that students progress from being *accurate* readers only to also being *fluent* readers. The importance of creating skilled, independent readers cannot be underestimated, as such ability impacts participation in classroom learning opportunities, and later employment and social opportunities. RR is a popular and successful strategy used to promote reading fluency which receives some support from the current findings and those of other researchers, which suggest that it is effective for improving fluency on both passages that are re-read and those that are untrained.

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Appendix (Ethics Approval) of this thesis has been removed as it may contain sensitive/confidential content