BEHAVIOURAL READING™
POD Software
Research Basis 2015

The following literature review conducted late 2015 forms the research basis of Behavioural Reading™ and POD Software that is currently used by Educational Professional (EPs) and speech pathologists as part of a multi-component intervention approach to literacy difficulties in a private speech pathology clinic in Bulimba Queensland, Australia. Both Behavioural Reading™ and POD Software are also available commercially via online subscription.

LITERATURE REVIEW

According to the Australian Bureau of Statistics, 4% of Australia's population aged 15 and over have difficulty reading brief texts on familiar topics (Australian Bureau of Statistics, 2013). Although EPs utilise the K-10 English Syllabus (Board of Studies NSW, 2012) and New South Wales Literacy Continuum (State of New South Wales Department of Education and Communities, 2013) to monitor literacy development and plan lesson goals; it is up to the individual teacher and/or school policy as to what assessments, strategies or programs are utilised (Aaron, Maleta Joshi, Gooden and Bentum, 2008).

Based on Serry's (2013) qualitative research, Serry indicated confusion in the school setting including the roles EPs, speech language pathologists (SLPs) and other professionals play in remediation of literacy difficulties. This is not surprising given the vast amount of literature relating to diagnosis and treatment of reading disabilities and the lack of efficacious reading intervention approaches utilised by teachers in Australian schools (Australian Council for Education Research (ACER), 2013).

WHAT IS KNOWN ABOUT THE CAUSATION OF LITERACY DIFFICULTIES?
An Overview

<u>Biological Aetiologies – Imaging Studies</u>

Snowling & Stackhouse (2006) summarised findings from brain-imaging studies that provided evidence for the existence of a biological basis in the brain for developmental reading difficulties also termed 'developmental dyslexia' in the literature. A commonality to phonological studies is that phonological processes, such as segmentation and assembly fail to activate the brain in a typical manner and with optimal efficiency. Snowling and Stackhouse also reported that studies investigating word recognition have shown that relevant information may gain access to the language areas in the left hemisphere of the brain via an inefficient route. Brain imaging in children pre-and post intensive therapy has also shown a change in brain functioning towards that of typically developing readers (Snowling & Stackhouse, 2006).

Wolf, M. (2008) described the brain of the novice reader to undergo comparatively more activity in both hemispheres as learning new skills requires greater cognitive and motoric processing and underlying neuronal territory. Wolf noted that as skills become highly practised, there is less cognitive expenditure, and the neuronal pathways also become streamlined and efficient. Wolf reported that fMRI studies have found that children use more specific regions of the brain compared to adults such as the angular gyrus and supramarginal gyrus that are both important structures for integrating phonological processes with visual, orthographic and semantic processes.

In a review of the aetiology of dyslexia, Norton and Wolf (2012) reported that in comparing people with dyslexia relative to control groups of participants, the most consistent finding is an under recruitment of left temporo-parietal and left occipito-temporal areas. In contrast, younger children without dyslexia and matched for reading ability do not show under recruitment of these areas (Hoeft et al., 2007). Hoeft et al. also commented on individual studies identifying greater activation of the right frontal and temporal lobes for people with dyslexia relative to control groups. Hoeft et al. hypothesised that additional activation of neurological processes are thought to represent compensatory mechanisms or inefficient and effortful processing.

According to Norton and Wolf (2012) diagnosis of dyslexia is not absolute due to the many processes required for reading. Norton and Wolf highlighted that inaccuracy at any level of language or processing or a lack of automaticity in connecting any of these circuits can lead to poor reading. Norton and Wolf reported the tasks used in nearly all brain imaging studies to date have focused on accuracy rather than fluency.

In a study that engaged typical adult readers to read sentences presented at rates slower than, equal to, and faster than their normal reading speed, the posterior middle temporal gyrus was engaged at all reading speeds, whereas areas of the left inferior frontal gyrus and occipito-temporal regions were more active at both slow and fast, but not normal, speeds (Benjamin & Gaab, 2011). Results were compared to a letter-reading baseline task and Benjamin & Gaab suggested that when the automaticity of normal reading is disrupted, activation in reading-related regions changes, consistent with a multicomponent view of fluency.

Theoretical Explanations

A variety of theoretical explanations as to the causation of literacy difficulties have been hypothesised. In summary, these include the phonological theory, the cerebellar theory and the magnocellular theory (Ramus, Rosen, Dakin, Day, Castellote, White and Frith, 2003). Per Prideaux, Marsh and Caplygin (2005) cerebellar theorists postulate that the range of deficits associated with dyslexia can be attributed to a mild dysfunctional cerebellum evidenced by difficulties with skills such as balance, postural stability, motor coordination and automatisation. The phonological theory has at its core of dyslexia, a cognitive deficit in phonological awareness, whereas magnocellular theorists propose both auditory and visual temporal processing deficits resulting from impairment of neural pathways involving large magno cells (Prideaux et al., 2005).

Phonological Theory

Cognitive processing difficulties as to the underlying cause of specific language impairment (SLI) as well as dyslexia have also been proposed (Claessen, Leitao, Kane & Williams, 2013). Wagner and Torgesen (1987) described the phonological processing model to be three separate but linked phonological abilities: phonological awareness, phonetic coding in working memory and phonological recoding in lexical access. Claessen et al. (2013) assessed 63 participants with a battery of tests based on the psycholinguistic framework proposed by Stackhouse and Wells (1997). Claessen et al. (2013) found that the spread of scores on all measures of phonological processing was wider than that of the age-matched and language-matched groups on most tasks demonstrating a different profile of phonological processing.

Baddeley (1992) has suggested that there is a dynamic relationship between working memory, long-term memory, information processing systems, language ability and world knowledge. Baddeley (1986) described working memory as active processing rather than passive storage of information in primary (short term) memory. Baddeley's Working Memory Model includes the Phonological Loop, Visual-Spatial Sketchpad and Central Executive Function.

The Phonological Loop has received the most empirical support having explained robust effects such as phonological similarity, irrelevant speech, word-length and articulatory suppression effects (Baddeley, 1992). In a recent study investigating comprehension difficulties in children, Pimperton and Nation (2014) analysis of group differences revealed that working-memory-related problem behaviours were noted for a small subgroup of poor comprehenders who also displayed domain-general (verbal and nonverbal) working memory difficulties. Pimperton and Nation argued there to be "genuine" underlying working memory deficits for some students with comprehension difficulties.

According to Salway and Logie (1995) the Visual-Spatial Sketchpad has been shown to play an important role in mental imagery tasks and planning of movements. The Visual-Spatial Sketchpad is thought to include a passive visual temporary store that processes visual properties of objects and scenes and an active spatially based rehearsal system (inner scribe) that is involved in the planning and cognitive control of movement. Pham and Hasson (2014) explored the relation between verbal and visuospatial working memory and reading ability in a sample of school-aged children (n=157 ages 9-12) with a wide range of reading skills. Although results indicated that verbal working memory was a stronger predictor in reading fluency and comprehension, visuospatial working memory also significantly predicted reading skills providing greater variance in reading comprehension than reading fluency.

The Central Executive Function has been proposed to coordinate the flow of information within working memory by encoding and retrieving information from the Visual-Spatial Sketchpad and the Phonological Loop (Baddeley, 1986). Gillam, Hoffman, Marter, & Wynn-Darcy (2002) suggested that adequate Central Executive Function in working memory is necessary for the development of coherent mental representations in long-term memory and these representations form the semantic network that is the basis for language development.

Working Memory and Literacy Development

Daneman and Carpenter (1980) postulated that working memory capacity plays a crucial role in reading comprehension given the reader must store pragmatic, semantic and syntactic information from the preceding text and use it in the subsequent text. Information in working memory may be lost through decay or displacement since its capacity is assumed to be limited. Daneman and Carpenter hypothesised a good reader to require fewer processes than a poor reader and be more efficient having fewer computational demands on working memory and therefore greater capacity. An efficient process would also be functionally faster, resulting in less decay of the preceding information (Daneman and Carpenter, 1980).

Berninger and Abbott (2013) suggested that superior verbal reasoning might mask dyslexia if only very low achievement is used for diagnosis. Berninger and Abbott studied 64 children in Grades one to nine who had either superior verbal reasoning or average verbal reasoning. Students with superior verbal reasoning and dyslexia significantly outperformed those with average verbal reasoning and dyslexia on reading, spelling, morphological, and syntactic skills, but not on verbal working memory tasks.

Like phonological working memory, phonological awareness, the ability to hold and manipulate the sound component of language has been linked to early reading as well as spelling achievement. Gillam and Kleeck (1996) reported that phonological awareness can occur at syllabic, sub-syllabic and phonemic levels and phoneme-level representation of speech gradually emerges during the preschool years. Gillam and Kleeck (1996) asserted that phonological working memory is necessary for performing phonological awareness tasks because the phonological coding and recoding processes that are a part of phonological working memory are also necessary for phonological awareness.

Brady (1991) described weak meta-phonological awareness skills to be implicated in dyslexia however verbal working memory problems to also be a common occurrence. In support, evidence from a small study investigating the condition hyperlexia; Healy, Aram and Horowitz (1982) found that despite the 12 participants having very low cognitive functioning, performance on working memory tasks stood out as one of the few cognitive strengths of these children.

Rapid Autonomic Naming and Literacy Development

According to Norton and Wolf (2012), Rapid Autonomic Naming (RAN), the task of naming a series of familiar items as quickly as possible appears to invoke a mini-circuit of the later-developing reading circuitry. Norton and Wolf (2012) cited an extensive body of research that supported RAN tasks as one of the best predictors of reading fluency across all known orthographies. Regarding research in this area, RAN tasks and reading have been proposed to require many of the same processes including, eye saccades, working memory, connecting of orthographic and phonological representations. As required for reading fluency, RAN tasks also depend on automaticity within and across each individual component in the naming circuit.

APPROACHES TO LITERACY INTERVENTION

Norton and Wolf (2012) reported that reading has been compared to rocket science and to conducting a symphony, yet it is expected children to have mastered the requisite and complex set of skills required for reading by the age of seven, including integration of a vast circuit of brain areas both accurately and efficiently. This "reading circuit" is composed of neural systems that support every level of language, phonology, morphology, syntax, and semantics as well as visual and orthographic processes, working memory, attention, motor movements, and higher-level comprehension and cognition (Norton & Wolf, 2012).

Wolf (2008, p.130) defined 'developmental reading fluency' as not a matter of speed but a matter of being able to utilise all the knowledge a child has about a word (e.g. letters, letter patterns, meanings, grammatical functions, roots and endings) in time to think and comprehend. Becoming fluent is therefore being able to both read and understand. Wolf however reported that fluency does not ensure better comprehension but provides additional time to the executive system (such as working memory) to direct attention where it is most needed to infer, understand, and predict. For example, Wolf reported that "sight-words" and "sight chunks" (e.g. morphemes such as prefixes 'um', 'pre' and suffixes 'er', 'ing') increase semi-fluency in the decoding reader. Wolf noted however, children rarely receive explicit instruction in morphological knowledge being one of the least exploited aids to fluent comprehension. Bell (1991) also summarised historical perspectives regarding the relationship between imagery and cognition required for reading comprehension and indicated that reading fluency is a product of efficient formation of visual imagery when decoding.

Norton and Wolf (2012) noted that improving RAN ability and reading fluency is much more difficult. Reasons stated included RAN tasks to be a surface indicator of the efficiency of the underlying processes shared by naming and reading. There have been no large-scale, well-controlled studies that have tried to explicitly train naming speed. Norton and Wolf reported that their own studies have shown that although best interventions can improve most reading and language variables, the RAN changes little from pre-to post treatment, suggesting that RAN taps a more basic index of processing.

Fluent comprehension depends on accuracy and automaticity at every level of language, although Norton and Wolf (2012) noted few intervention programs reflect this. Morris et al. (2011) examined the impact of intervention for 279 students with reading difficulties. Students were randomly assigned to one of four different intervention programs designed to contrast different types of instruction: (a) study skills and math instruction (no reading instruction), (b) a phonological program plus study skills instruction, (c) a multi-component word-identification strategy and phonological program, or (d) a multi-component program designed to address each level of reading (Wolf et al. 2009) and a phonology program. Students were matched for IQ, race, and socioeconomic status among groups, and each group received 70 hours of small-group instruction.

Results showed that children who received multi-component interventions (options (c) and (d)) had significantly greater growth than did other intervention groups on timed and untimed word and non-word reading and passage comprehension tasks. In terms of fluency, children in the multi-component (d) group also outperformed the other interventions, gaining more than six standard score points on the Gray Oral Reading Quotient (Morris et al. 2011). Per Morris et al. results highlighted the importance of explicitly addressing the multiple levels of language and multiple cognitive processes involved in reading, especially for students with RAN or double deficits whose weaknesses are not adequately addressed by a phonological decoding program alone.

Aaron et al. (2008) described three approaches to literacy intervention: Discrepancy Model of Learning Disabilities (LD), Response to Intervention (RTI) and the Component Model of Reading (CMR). LD is defined in terms of average or above-average intelligence but below average reading performance.

The discrepancy model has been scrutinised for failing to deliver expected academic benefits. The primary reasons for poor outcomes of LD instruction being the unsystematic way children with LD are taught and lack of uniformity in instructional methods (Vaughn, Levy, Coleman and Bos, 2002). Aaron et al. (2008) reported the quality of reading instruction provided within the LD model is driven by the whole-language philosophy and relies heavily on group work, disregarding individual needs.

As an alternative to the discrepancy model, Response to Intervention (RTI) is embedded in a multi-tiered model of assessment, intervention and progress monitoring (Kovaleski, 2004). Phases are hierarchical being initial classroom instruction followed by intense instruction for at risk students and effect measured. Individualised instruction is provided to those students below average and referred to special education services. Like the LD model there are several variants or approaches to RTI and the focus of RTI being ‘identification of literacy difficulties’ and not on the ‘specific method of instruction’ has been criticised (Aaron et al., 2008).

Implementing the Component Model of Reading (CMR) involves identifying the weak component that underlies reading difficulties and focusing remedial efforts at the weak component or components (Aaron, et al., 2008). To be considered a component, the process must be independent of other cognitive processes (Sternberg, 1985). The three domains of the CMR are the cognitive domain, the psychological domain and the ecological domain. The cognitive domain has two components: word recognition and comprehension. Per Aaron et al. (2008), when the CMR model is applied to literacy acquisition, a student can fail to acquire satisfactory levels of literacy skills because of deficits in any component in any one of the domains. As well as comprehension, the second component of the Cognitive Domain includes two processes – the ability to decode written words and the ability to decode words instantly and automatically.

Aaron et al. (2008) conducted two studies, the first to validate the CMR method and second to compare CMR-based instruction versus Discrepancy based instruction. In the first study Aaron et al. used a battery of reading assessments on children in grades 2 through 5 at different schools in the United States. Aaron et al. reported that the two components of the CMR cognitive domain, listening comprehension and decoding could predict from 38% to 41 % of the variability seen in reading comprehension. They found however that fluency makes inconsistent contribution to reading comprehension, accounting for a negligible 2.5% of the variance at the fifth-grade level.

In the second study, the reading achievement scores of a total of 330 children from Grades 2 through 5 were used for comparing the effectiveness of instruction based on the cognitive component of the CMR model (171 students) (utilising the READ program for sound and word recognition and a seven step comprehension strategy) with that of instruction based on the traditional LD model (159 students). Results indicated generally that instruction provided under the framework of the CMR was more effective than undifferentiated resource room instruction (Aaron et al., 2008).

Aaron et al. summarised outcomes stating that word recognition provided to children with a deficit in that component is more effective than undifferentiated instruction provided to children with LD. In addition, children who received training in word recognition skills showed significant gains in comprehension however children who received comprehension training but who had word recognition difficulties did not improve in word recognition skills. In contrast, children who had sufficient word recognition skills but weak comprehension skills improved reading comprehension with comprehension training.

Numminen (2002) reported many researchers in the field to have expressed doubts regarding rehabilitation of working memory. Numminen proposed however the use of plain language as a tool to improve working memory capacity. Numminen stated that reduced working memory capacity could be improved by selecting material that places less of a burden on linguistic working memory. Clear, well-paused and structurally short sentences and familiar vocabulary facilitates the functioning of working memory and makes it easier for a person to link new information to old information. This activation of deep processing during reading then assists in reading comprehension.

Prideaux, Marsh and Caplygin (2005) investigated the efficacy of Cellfield™ computer based Intervention for 262 Australian school children tested pre-and post treatment. The Cellfield™

Intervention is based upon the multi-deficit hypotheses (phonological, cerebellar and magnocellular) of dyslexia using computer-based tasks requiring visual, auditory and phonological processing. Intervention comprised of ten one-hour sessions, each consisting of ten exercises. The study provided preliminary support for the efficacy of the Cellfield Intervention with results demonstrating improvements in reading related skills, oral reading proficiency and ocular measures in the clinical sample assessed.

Prideaux et al. (2005) reported dyslexia intervention studies that achieve reading age gains of two months per one month of intervention as effective. Word attack skills were reported to be the most improved following Cellfield™ Intervention (23 times per one month of intervention). Improvements in 'reading words without context' and passage comprehension demonstrated meaningful gains of 12 times per one month. Spelling skills were reported to have improved but not significantly (Prideaux et al., 2005). Prideaux et al. reported limitations of the study to include potential sampling bias as participants paid for intervention. Further research was also recommended to establish the long-term benefits of the Cellfield™ Intervention and whether ongoing learning support such as phonological awareness therapy would augment gains.

Wong, He and Chan (2014) also investigated the effectiveness of computerised working memory intervention among Chinese students. General linear model analysis (repeated measures) was applied to neurological and behavioural measures obtained for working memory, response inhibition, and inattention and hyperactive symptoms for two groups of students, experimental and control. For the experimental group that received high-intensity training in the school setting, there was a significant improvement in working memory reflected in neuropsychological measures as well as parent-rated behavioural measures compared with the control group. Wong, He and Chan concluded that results supported the effectiveness of group-based computerised training and that it might be a cost-effective intervention in semi-structured settings, with high-intensity training and minimal therapist involvement.

Brent (2004) reported that automatic knowledge of sound-symbol correspondence must be well developed to compensate for limitations in working memory and to allow quick access to information stored in long-term memory and less reliance on executive processing. It typically takes many years for students with language impairment to achieve a literate level and that students with deficits in memory and the phonological module require teaching of detailed sound-symbol correspondence, for single and multiple letter groups, sound sequencing and division of words into syllables (Brent, 2004). In a study by Gillam and Kleeck (1996), they also supported the usefulness of phonological awareness training with children with language impairment and that phonological awareness training correlated with early literacy ability.

LITERACY ASSESSMENT AND INTERVENTION AT TYQUIN GROUP SPEECH PATHOLOGY AND READING CLINIC (Tyquin)

Consistent with what is reported in the literature, Tyquin SLPs and EPs assess students with literacy difficulties using the multi-deficit model of reading difficulties and base treatment on the component model of reading intervention (particularly the cognitive domain). In summary, students referred to the clinic with literacy difficulties are assessed using a battery of assessments (based on age) to identify specific areas of weakness or impairment. Literacy intervention provided is based on both theoretical and evidence-based research (phonological and phonemic awareness training), POD computer based intervention (auditory and visual processing), Behavioural Reading™ (instruction of reading technique) and participant's individual needs at the time (e.g. language intervention).

As discussed above, phonological awareness intervention has been researched extensively and the use of computer-based software has some evidence base to support its use in the treatment of literacy difficulties. Working memory difficulties and its association with reading difficulties is also well reported in the literature. Strategies such as 'chunking', reducing reading rate and the use of mnemonic strategies are often recommended to assist students with working memory difficulties. The implementation of such strategies to improve literacy skills, particularly reading fluency has not been researched extensively. Behavioural Reading™ and POD software are research based intervention approaches integrating such recommendations cited in the literature.

BEHAVIOURAL READING™

Behavioural Reading™ developed by Philip Gruhl (Gruhl, 2013) comprises several techniques that stem from a philosophical position based on a combination of research and evidenced based teaching principles and methodologies across a diverse range of disciplines including education, speech pathology, psychology, neuroscience, coaching and elite performance. Techniques are applied to reading, number and mathematical tasks and are conceptual in nature to prepare the archaeological pre-reading and number brain to adapt in such a way as to facilitate efficient functioning of these tasks (Wolf, 2008).

The philosophy extends to:

- Define a set of skills, interactions, neurological and emotional conditions that are typically seen in high performing individuals. The assumption is made that all skills are critical to the efficient acquisition and implementation of reading and number;

- The idea that through specific short term exercises, the underlying neurological sequences and timing seen in proficient individuals should be able to be instigated and built as per neuroplasticity theory;

- The concept of automaticity as an efficient neurological condition for a given task thereby mitigating working memory deficits;

- Growth of an efficient reading and number brain is best instigated and refined using a small volume of text, such as a single sentence, numbers 0 - 9 or simply a short sequence of 'up and down' arrows;

- Techniques should be initially learnt in a less demanding environment and this enables the efficient acquisition of fluent reading and comprehension to age appropriate skills following the initial skill acquisition and not vice versa; and

- Skills can be taught and learned to a level of automaticity in what would be regarded as fast (days and weeks) and easily (with little effort or time commitment) in contrast to the months and years typical of current methodologies used with tier 3 students (Gruhl, 2013).

POD SOFTWARE

The prescribed use of POD (10 daily sessions of one hour each) is designed to enhance Behavioural Reading Techniques, hypothesised to open new neural pathways and 'create the learning mind'. POD intervention is based upon the multi-deficit hypotheses (phonological, cerebellar and magnocellular) of dyslexia using computer-based tasks requiring central executive processing, sequencing, visual and auditory processing as well as phonological awareness skills. POD is web based and available via online subscription.

The initial design stimulus of POD is based on several software programs commercially available that may or may not have been used in the Tyquin Group Speech Pathology and Reading Clinic over the last decade. The design of POD in its delivery and content has evolved following the global improvements in computer technologies and web speeds.

Measurement and observation of student responses using standardised testing and anecdotal data has provided direction for POD software design to improve foundation skills necessary for reading including:

- Visual perceptual skills (visual tracking, visual memory, visual discrimination, visual form constancy and visual closure);
- Auditory perceptual skills particularly auditory discrimination;
- Phonological awareness skills; and
- Central executive sequencing.

Use of POD is prescribed and recommended for students eight years and over who have not been diagnosed with epilepsy or other neurological disorder. In addition to task requirements, students are encouraged to verbalise what they are doing, alternate coloured and clear glass lenses between the right and left eye (to increase the visual load and central executive loading to alternate hemispheres), tap out phonemes and read letter combinations phonetically (nonsense words).

Directly following the ten POD intensive sessions, students are instructed to read using the Behavioural Reading™ techniques. By combining the two therapies, it is anticipated that improvements in processing and phonological awareness skills combined with explicit reading instruction are transitioned into effective and efficient reading behaviours.

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