What is the relationship between phonological awareness abilities and literacy and speech-in-noise measures in school-aged children diagnosed with auditory processing disorder?

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Abstract

Dyslexia is related to difficulties with phonological awareness skills. Therapy for improving phonological awareness is recommended for management of dyslexia, but also for auditory processing disorder (APD). Research has found a relationship between reading disorder and APD, but that relationship is not well understood. A theoretical proposition is that problems processing auditory signals are related to poor phonological awareness and to reading failure. This study outlines the collection and analysis of the phonological awareness skills of school-aged children diagnosed with APD. It further analyses whether there is a relationship between phonological awareness ability and literacy measures, and a speech-in-noise test.

A mixed-methods study was designed to investigate 30 children diagnosed with APD (aged between 7 years 6 months and 10 years 1 month) in Auckland, New Zealand. Quantitative data were gathered from a standardised assessment of phonological awareness, tests of literacy abilities (reading fluency, single-word spelling and grapheme–phoneme correspondence knowledge) and a speech-in-noise test. Qualitative data were collected from a parent/caregiver's response asking if the child had a history of dyslexia.

The children's mean composite score of phonological awareness ability was below average with distribution of percentiles across the lower ranks (range was 1 to 63). Reading fluency and parent/caregiver's report of dyslexia were the strongest predictors of underlying phonological awareness difficulties. There were statistically significant correlations between phonological awareness and single-word spelling and grapheme–phoneme correspondence. Phonological awareness did not correlate with the speech-in-noise measure. A recommendation from the findings is that a parent/caregiver report of dyslexia and a test of reading fluency will indicate the presence of underlying phonological awareness difficulties in school-aged children with APD.

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Dedication

I dedicate this to parents everywhere, the true warriors of the world. Until I became the mother of a child with dyslexia and APD, I didn't realise that I would need so much more than love for her. I would need both courage and knowledge too. So we surge forward every day learning, supporting and advocating endlessly. This thesis has been part of my journey.

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Glossary

Amplitude	Sound volume, as measured by the height of the sound wave.
Auditory brainstem response	Auditory evoked potentials extracted by electrical activity in the brain (recorded via electrodes positioned on the scalp).
Auditory event-related potentials	Small voltages generated in the brain in response to auditory stimuli. See cortical auditory evoked potentials (CEAPs).
Categorical perception	Perception of distinct categories when there is a gradual change in a variable along a continuum. CP is an important phenomenon in cognitive science because it informs us about how we adapt perception to support categorisations we need to make. CP was originally observed for auditory stimuli and is now applied to other perceptual modalities such as speech. In the speech-perception context, CP allows us to distinguish between sounds, regardless of how similar or different they are. For example, we can distinguish between the sounds of *b* and *p* by a voice onset time of only 0.06 seconds (the time delay between the lips releasing and the vocal cords vibrating).
Cognition	The mental processes involved in gaining knowledge and comprehension. These processes include thinking, knowing, remembering, judging and problem-solving: the higher level functions of the brain (encompassing language, imagination, perception and planning).
Cortical auditory evoked potentials	Bioelectric function of the auditory pathway in response to sound stimuli. The most common test is the auditory brainstem response (ABR).
Developmental language disorder	A condition where children have problems understanding and/or using spoken language.
Dichotic listening	Listening with both ears, which involves 1) binaural integration: the ability to perceive different acoustic messages presented to the left and right ears at the same time, and 2) binaural separation: the ability to perceive an acoustic signal in one ear whilst ignoring a different acoustic signal in the other ear.

Dichotic digit test	Two pairs of double digits are presented to the ears simultaneously. The listener verbally reports back the four digits.
Electrophysiology	Physiology concerned with the electrical phenomena which occurs in the nervous system (and other bodily systems).
Frequency	Sometimes called “pitch,” frequency is the level of intensity of specific tones which a person can hear—measured in Hertz (Hz).
Frequency discrimination	The ear's ability to perceive the difference between two pure tones of different frequencies (of the same decibel level).
Frequency pattern test	The listener is presented with three tones of varying pitch which the listener verbally identifies as high or low pitch (in the correct order/pattern).
Gap detection	Detecting temporal gap to identify when two auditory stimuli are heard as one sound or two.
Grapheme–phoneme correspondence	The knowledge that a certain grapheme corresponds to a certain phoneme. GPCs are used by us when we read. English has a low GPC, especially for vowels e.g., the letter *a* can correspond to multiple phonemes depending on its position in the word, its language derivation source, morphological rules etc. Other languages, such as Spanish, have more consistent GPC.
Masking level difference	Detecting a tone when presented in noise that is phase-shifted between the two ears.
Monaural low redundancy	The ability to achieve auditory closure when information is missing.
Monaural low redundancy test	A test in which the speech signals have been altered electronically (by removing portions of the original speech). Used to assess a person’s ability to auditorily cloze when parts of the message are missing.
Pitch pattern perception	The ability to perceive differing pitch patterns. See frequency pattern test.
Gap-detection test	Tones are presented separated by gaps and the listener identifies whether they have heard one tone or two.

Rise time	The ability to discriminate the rate of change in amplitude of a sound over time.
Slow rise time	The slowly varying amplitude in speech.
Soundbooth	A small enclosed sound-proof room.
Spatial segregation	The ability to localise, lateralise and analyse auditory information from simultaneous sound sources. It is an important skill for speech perception in the presence of competing messages.
Spectrotemporal	Describes anything to do with the time and frequency of the wavelength.
Speech-in-noise	Audiological term for the ability to hear and understand speech in the presence of background noise.
Stimulus individuation tasks	Judging whether sequentially presented auditory stimuli depict the same stimulus or different ones.
Temporal processing	The processing of acoustic stimuli over time. An important component in the ability to understand speech in background noise.
Tympanometry	A test of middle ear functioning which looks at the flexibility (compliance) of the ear drum (tympanic membrane) to changing air pressures. How compliant the ear drum is indicates how effectively sound is transmitted into the middle ear.

Table of Abbreviations

Abbreviation	**Explanation**
AAA	American Academy of Audiology
ABR	Auditory Brainstem Response
ADHB	Auckland District Health Board
APD	Auditory processing disorder
ASHA	American Speech and Hearing Association
BKB-SIN	BKB-SIN Speech-in-noise test. Etymotic Research, Inc
BKBSNR	BKB-SIN signal-to-noise ratio
CTOPP-2	Comprehensive Test of Phonological Processing—Version 2
CAEPs	Cortical auditory evoked potentials
CRW	Compressed and reverberated words test[1]
DDT	Dichotic Digit Test[1]
DWT	Dichotic words[1]
FPT	Frequency pattern test[1]
GPC	Grapheme–phoneme correspondence
LeST	Letter-sound test
LiSN-S	The Listening in Spatialized Noise– Sentences Test[1]
NRP	National Reading Panel
NZ	New Zealand
NZSTA	New Zealand speech language association
MRI	Magnetic resonance imaging
NU-6 1KHz LPFW	North Western University Auditory Test 6 Low-Pass Filtered Words Test at 1KHz[1]
PGC	Phoneme–grapheme correspondence: the knowledge that a specific phoneme corresponds to a specific grapheme. PGCs are used to help us spell. PGCs do not always correspond to GPCs.
PPT	The Phonological Processing Treatment for Children with Auditory Processing Disorder research study
QUIL	Queensland University Inventory of Literacy Assessment
RDDT	Randomized Dichotic Digit Test[1]
RGDT	Random Gap Detection Test[1]
SAST	South Australia Spelling Test (Revised)
SCAN-3	SCAN–3 Tests for Auditory Processing Disorders in Children, Adolescents and Adults[1]
SD	Standard deviations
SLT	Speech-language therapist

SPELD NZ	SPELD NZ is a not-for-profit organisation that specialises in assisting people with dyslexia and other specific learning disabilities
SVR	The simple view of reading
TDH	Audiometric headphones manufactured by Telephonics widely used in the industry to deliver precise sound replication (high sensitivity and low distortion, etc)
WARP	Wheldall Assessment of Reading Passages
wcpm	Words correct per minute. A measure used by the Wheldall Assessment of Reading Passages
8.08	This signifies the age of 8 years and 8 months

[1] = Behavioural test for APD

CHAPTER 1. Introduction

This study is concerned with two main bodies of scientific research related to phonological awareness: 1) reading acquisition and failure and 2) auditory processing disorder (APD). The research in these areas is commonly conducted by two different professional groups; reading research is primarily conducted by educationalists, psychologists and speech-language therapists (SLTs), whilst APD research is mainly conducted by audiologists and hearing scientists. These two professional groups come from differing philosophical models of practice and research: psychoeducational and medical. Phonological awareness, or more specifically phonemic awareness, is the focus of the current study because it is a sensitive predictor of successful reading acquisition (Ehri et al., 2001; Neilson, 2009) and because of its connection with APD and reading disorders. Phonological awareness is the term used by this study but with recognition that it encompasses the subcategorical term *phonemic awareness*. Research supports the theory that children who have good phonological awareness are good readers and those that do not, may struggle (Blachman, 1997; Bradley & Bryant, 1983; Gillon, 2018 Liberman, Shankweiler, Fischer, & Carter, 1974). Some researchers of APD in hearing science believe that phonemic awareness is the intercept between disorders of auditory processing and reading. Despite emerging recognition in the literature that both the disorders of dyslexia and APD are somehow related, and that phonological awareness may play a role connecting the two disorders, the research in reading and hearing sciences has rarely overlapped in any substantive way until relatively recently (See Appendix A). However, cross-pollination of knowledge at conceptual, clinical and research level could benefit practitioners in reading and hearing disorders. The current study was designed to consider both the reading science and hearing science perspectives of phonological awareness and its role in dyslexia and APD. This study was designed to clarify the relationship that phonological awareness has with literacy within a sample of school-aged children diagnosed with APD. It was conducted by an SLT with an interest in using knowledge from different professional groups and research fields to benefit children who have a diagnosis of APD.

Phonological awareness is an area of expertise for SLTs treating *speech-sound disorders* of a phonological nature. In contrast, the use of phonological awareness for assessing and treating APD and dyslexia are not routine areas of practice for most SLTs in New Zealand (NZ). Nonetheless, professional bodies continue to recommend that SLTs use phonological assessments and therapies for APD and dyslexia management (Chermak, Silva, Nye, Hasbrouck, & Musiek, 2007). SLTs are facing increasing referrals from audiologists for children with APD for whom phonological interventions have been recommended. However, SLTs anecdotally report difficulty understanding APD test results and the impact they have on a child’s literacy abilities. Consequently, SLTs commonly seek information from parents/caregivers and teachers, and conduct psychoeducational tests to reveal functional breakdowns in literacy, phonological awareness and possible avenues for therapy. Similar avenues have been explored by this study’s methods. The motivation for this study was to support the practice of SLTs in the field.

In this study, I take a closer look at school-aged children diagnosed with APD and aim to ascertain whether a standardised, readily available and well-known psychoeducational test (Comprehensive Test of Phonological Processing—Version 2 [CTOPP-2]) detects any phonological awareness problems. In addition, this study aims to find a relationship between the children's phonological awareness ability, a parent/caregiver report of dyslexia, reading fluency, spelling, grapheme-phoneme correspondence and speech-in-noise measures. To say there is a vast body of research in the field of reading science is an understatement, but the study will specifically focus on phonological awareness in reading research. The hope is that by assessing phonological awareness in children with APD, useful knowledge will be added to the literature to better understand the relationship between APD and reading failure.

This is a timely study given that both APD and dyslexia are under scrutiny due to a lack of recognition and understanding of their impact on NZ school children. Heightened pressure for management guidance in both APD and literacy domains has driven the release of two recent documents: 1) *New Zealand Guidelines on Auditory Processing Disorder* (Keith, Purdy, Baily, & Kay; 2019), and 2) *Massey University Early Literacy Research Project: Final Report* (Chapman, Arrow, Braid, Greaney, & Tunmer, 2018). Both documents were commissioned by government ministries and have implications for speech language therapy practice. Both documents highlight the important role that phonological awareness plays in the assessment and intervention for disorders of auditory processing and reading.

This study is set within an NZ context, but due to a paucity of local research in the relatively localised and recent field of APD, international studies have been cited. It draws strongly from the premise of previous NZ APD research which found that auditory deficits are related to reading disorders (Sharma, Cupples, & Purdy, 2018; Sharma, Purdy & Kelly, 2009, 2012; Sharma et al., 2006). Methodologically, the current study differs from Sharma and colleagues (2006; 2009, 2012; 2018) in the following ways: the term dyslexia is used, rather than "reading disorder," as a descriptive term for the reading difficulties experienced by the children in the sample (Sharma et al, 2009, 2012; Sharma et al., 2018), the current study has a smaller sample size, a narrower sample age range and a slightly different test selection. The term dyslexia was chosen because it focuses on phonological awareness as the key skill inhibiting successful reading, as opposed to reading disorder which can encompass wider language-related issues (poor vocabulary), and/or reduced literacy opportunity, as causes of reading failure.

In the following chapters, the term APD will be used, but this includes research from the outmoded term central auditory processing disorder (CAPD). Diagnosis of APD is commonly made within the school years, and it is for this reason that school-aged children make up the sample for the current study. APD as a separate diagnostic entity, the diagnostic test battery and recommended managements are topics debated at length in the literature but not explored here in any great detail, except where they shed light on the differing philosophical frameworks influencing a professional's view on phonological awareness and its role in assessing and treating APD. Like other research and discussions about APD, I endeavour to provide information to better understand the profile of children with APD. The client's needs have been kept in mind throughout, and whilst I acknowledge the comorbidity of APD with other neurological and learning disorders (Sharma et al, 2009), I do not fully explore these in any great detail.

I begin with a review of what the literature tells us about phonological awareness and its possible connections with dyslexia and APD, before moving on to describing the methods used, the results, discussion of possible implications to SLT practice and a final conclusion.

CHAPTER 2. Phonological awareness

SLTs understand that phonological awareness abilities are at the core of language processing and play an integral part in acquiring literacy (Gillon, 2018). The National Reading Panel (NRP; 2000) and Ehri et al.'s (2001) meta-analysis of over 10,000 research studies are often quoted as the point at which general education practitioners' attention was drawn to the critical role that phonemic awareness plays in literacy acquisition (alongside other key skills: vocabulary development, reading fluency and reading comprehension) (Ehri et al., 2001; NRP, 2000). The NRP (2000) concluded that for both children at risk of failure at the beginning-reading stages, and for older failing readers, explicitly training phonemic awareness is an effective approach to teaching reading, especially when combined with instruction in grapheme–phoneme correspondences (GPC). This chapter focuses on phonological awareness in reading and spelling acquisition in NZ and the role of the SLT, and discusses conceptual models of reading development. I begin with explaining what phonological awareness is and how it develops in children.

2.1 Phonological Awareness Explained

Phonological refers to the system of contrastive interactions among speech sounds of our language. *Awareness* refers to how we identify, perceive and manipulate these speech sounds. Therefore, phonological awareness (PA) is the knowledge that oral language comprises units of sound (word, syllables, phonemes) and explains the way we mentally handle these speech sounds (Gillon, 2004; Wagner & Others, 1997). Phonemic awareness, a subcategory of phonological awareness, describes the awareness of phonemes or "sounds" within words. The science of reading development is interested in phonological awareness (and phonemic awareness) because of its importance to the process of acquiring literacy. Unlike learning to speak, learning a *written* language is a biologically unnatural process dependent on developing the metalinguistic ability to connect phonemes (abstract auditory units) to corresponding symbols (graphemes) (Richardson & Lyytinen, 2014). GPC is reliant on phonological awareness (Stackhouse & Snowling, 1996). Phonological awareness encompasses awareness of the larger sound units present in speech, such as syllables, whilst phonemic awareness is concerned only with the phoneme-level skills (Gillon, 2018). Phonemic awareness is often considered a subset of phonological awareness and Table 1 illustrates the generally accepted continuum of phonological awareness skills from word-level skills, such as rhyme awareness at beginning school age of 5-years-old, through to complex phonemic-level skills: identification, segmentation, synthesis and deletion. Table 1 shows the final stages of phonological awareness involve the ability to delete or manipulate phonemes to construct new words. Researchers and practitioners use charts similar to Table 1 to assess and analyse the phonological awareness abilities of children using less or more complex tasks according to the developmental age and/or reading stage of the child.

Table 1

Developmental Sequence of Phonological Awareness Skill Acquisition with Examples (adapted from Gillon 2007, Goswami, 2000; Schuele & Boudreau, 2008)

Approximate age	Phonological awareness task	Example
5	Recognising rhyme	Which two rhyme? Bat, bug, hat
	Counting syllables	Dog (1 syllable) turtle (2 syllables)
5 ½	Blends onset and rime	b-oat, c-up
	Produces a rhyme	Tell me a word that rhymes with cat (rat)
	Identifies initial sound	Say the first sound in sat (s)
6	Syllable deletion	Say "tulip," now say it again but don't say "tu" (lip)
	Blending of 2–3 phoneme words	s-u-n (sun) b-ee (bee)
	Segments 2 and 3 phoneme words (no consonant blends)	Say the sounds in "beet" as you move a bead for each sound (b-ee-t)
6 ½	Segments words that have up to 3 or 4 phonemes (including consonant blends)	Say the sounds in "black" as you move a bead for each sound (b-l-a-k)
	Phoneme substitution to build new words (no blends)	
7	Phoneme deletion (initial and final word positions)	Say "seed." Now say it again without "d" (see)
8	Phoneme deletion/manipulation (initial position including blends)	Say "sled" now say it again without the "s" (led)
9	Phoneme deletion/manipulation (medial and final blend position)	Say "snail," now say it again without the "n" (sail)

2.2 Phonological Awareness Development in School-Aged Children

It is thought that exponential phonological skill acquisition occurs between the ages of 5 and 7 in a linear and progressively staged manner (Table 1) (Chafouleas, Lewandowski, Smith, & Blachman, 1997). Chafouleas et al. (1997) assessed 171 typically developing children and found phonological awareness skill acquisition levelled off at around age 7, primarily due to reaching a level of mastery. It was generally accepted that this development begins with the larger chunks of sound units, such as words and syllables, and develops through to an ability to identify the smaller units (phonemes) with each stage being more difficult to master than the next (Gillon, 2007). However, it is now clear that it is unlikely that phonological awareness skills are uniformly acquired by all children, or at the same stage and rate (Gillon, 2018). It may be that different phonological awareness skills appear and are required by children at different stages of reading development. Research from the hearing sciences has found that, for children with hearing loss, phonological awareness development follows a similar course to other children but the stages are delayed (James et al., 2005; Nittrouer & Caldwell-Tarr, 2016). Whether securing each phonological awareness stage is reliant on the acquisition of the former, is still open to debate (Gillon, 2018). Duncan and Johnston (1999) found that some older children have phonemic manipulation skills yet little ability to rhyme match, suggesting that rhyming skills have become less important as decoding and reading fluency developed. Indeed, it is more likely that phonological awareness skills may be needed more, or less, depending on the reading stage, ability, culture, language and learning context of each individual child. A NZ study found that in opposition to current thoughts on reading acquisition and its dependence on phonemic skills, Māori children in fact rely more on *syllable* units than *phoneme*-level skills when learning to read (Harris, 2009). Gillon (2019) quite rightly pointed out that there is still much debate in the literature about the possible age and sequence in which phonological awareness skills develop in children and whether they are in fact linear in progression or multifactorial outcome skills; clearly more research is required in this area.

2.3 Phonological Awareness and its Relationship to Reading

Reading science literature supports an established connection between phonological awareness and a child's future success establishing reading and spelling (Bradley & Bryant 1983; Lundberg, Olofsson, & Wall, 1980; Westwood, 2005). Ehri et al. (2001), in their meta-analysis of 52 peer-reviewed studies evaluating the effects of phonemic awareness instruction on learning to read, found it made a significant contribution to reading acquisition, with large and statistically significant effect sizes (d = 0.86) for improving phonological awareness, and moderate and statistically significant effect sizes on reading (d = 0.53). There remains debate about whether phonological awareness is a cause of reading success or failure, but general acceptance that there is, at least, an relationship between the two. This may be a bidirectional relationship between phonological awareness and reading for many early typically developing readers. Learning to read develops their phonological awareness and vice versa (Pogorzelski & Wheldall, 2005). This bidirectional and mutually facilitative relationship is less evident in children who struggle with reading. Children with dyslexia find that a lack of phonological awareness greatly inhibits their reading success (Vellutino, Fletcher, Snowling, & Scanlon, 2004). This is evident in the findings that phonological awareness instruction positively impacts all readers in preschool to early school years, but particularly those who are at risk of reading failure and/or those who are reading disabled (Ehri et al., 2001). It is known that phonological approaches are effective in the amelioration of reading and spelling disorders (Galuschka, Ise, Krick, & Schulte-Körne, 2014; Gillon & Dodd, 1997).

Phonological awareness instruction is more effective as a support for reading success when it is taught with letters, presumably developing the GPC skills necessary for decoding in reading (Ehri et al., 2001). Mastering the connection between the letters of the alphabet and the unique phonemes connected to them develops decoding and the ability to pronounce all words in that language, as well as invented words (pseudowords). It is widely accepted that this decoding ability is reliant on the development of GPC knowledge. Current reading acquisition theories state that the mapping of letters onto speech sounds is a skill that needs to be taught in a systematic, cumulative manner (Ehri et al., 2001). Researchers have long speculated that how we perceive, store and access these mental representations of phonemes might explain the link between phonological awareness and reading skills. Poorly specified or indistinct mental images of phonemes, when stored, retrieved, or accessed, affect the reading process (Elbro, Borstrøm, & Petersen, 1998). Table 2 shows the decoding subskills which must be mastered to read unfamiliar words and become a skilled reader (Stackhouse & Snowling, 2006). Interestingly, studies of high-functioning adults with dyslexia show that despite underlying phonological awareness deficits, they are able to compensate by using alternative stronger cognitive skills to develop functional reading (Reis, McGuire, & Neu, 2000; van Viersen, de Bree, & de Jong, 2019). However this is clearly not so for all readers and it is generally accepted that for *most* children with dyslexia, phonological awareness seems to be a necessary but elusive skill for acquiring reading fluency (Moats, 2017).

Table 2

Decoding Subskills for Reading (Adapted from Snowling & Stackhouse, 1996)

1. Phonological awareness: the ability to segment words into phonemes (speech sounds)
2. GPC: Grapheme–phoneme (letter-sound) correspondence and conversion. The ability to match letters to phonemes.
3. Blending phonemes to build a word
4. Identifying the correct word and its meaning.

2.4 Phonological Awareness and its Relationship to Spelling

It is generally accepted that phonological awareness is a necessary skill for acquiring not only reading, but early spelling ability as well (Westwood, 2005). Research has shown that poor phonological awareness is common among weak spellers (Notenboom & Reitsma, 2003), presumably because it inhibits the development of encoding skills (translating sounds into letters). Bradley and Bryant (1983) found a significant relationship between scores on the phonological awareness assessment of preschool children with their scores on spelling and reading tests three years later. Ehri et al. (2001), in their meta-analysis, found that phonological awareness instruction had a moderate and statistically significant (d = 59) impact on learning to spell. The process of acquiring spelling is controversial and dominated by two opposing views: 1) that spelling is a naturally acquired skill (it is “caught”) or, 2) that it is an unnatural skill which needs to be “taught.” In another example of a bidirectional and mutually facilitative relationship between two skills, caught theorists maintain that the very process of learning to read generates the necessary knowledge required for learning to spell. In opposition, taught theorists such as Dymock and Nicholson (2017) proposed acquisition of spelling is greatly assisted by systematic, explicit teaching of rules based on PGC for regular word spellings (those that can be phonically attacked), and that semantic rules, morphological and etymological knowledge, should be taught for learning to spell those words which are irregularly spelt (not able to be phonically attacked). Moreover, Dymock and Nicholson found that although “rule-based” spelling instruction and “no-rule” instruction were equally effective for learning a specific list of words, teaching “rule-based strategies” improved the ability to spell pseudowords (non-words but regularly spelt) which had a positive flow-on effect to the irregular words. Similarly, Graham and Santangelo’s (2014) meta-analytic review found that formal spelling instruction had positive effects on the phonemic awareness development of children, suggesting evidence of bidirectional facilitation of skills. Research from the hearing sciences reinforces the role of phonological awareness in learning to spell, by drawing attention to the great difficulties that deaf children have with developing encoding for spelling (Bowers, McCarthy, Schwarz, Dostal, & Wolbers, 2014). It seems that, like reading, most typically developing children may learn to spell without too much explicit or systematic instruction. But, like reading, it is not until a child has difficulty acquiring spelling that more direct instructional phonological awareness practice makes the difference between acquiring the skill successfully or not.

2.5 Phonological Awareness in New Zealand Schools

Since the 1970s, NZ has implemented a whole language approach to reading instruction and amelioration (reading recovery programme) in its school system (Tunmer et al., 2008). Marie Clay's (2016) whole language constructivist approach advocates for the child to use information from many sources (i.e., guessing the whole word from its context, cues from pictures and so on) when identifying unfamiliar words during reading and, rejects phonological skills as an unnecessary distraction to reading success. Research from the science of reading indicates that the absence of a phonological approach to decoding is a flaw in the whole language approach (Hicks & Villaume, 2000) and claims the best start for a child's literacy acquisition journey is an explicit, systematic, phonological approach. Supporting evidence from NZ research has found that explicit teaching of phonological awareness and PGC benefited struggling readers in reading recovery programmes (Chapman, Tunmer, & Prochnow, 2001). Whole language, as an approach, is becoming increasingly influenced by the science of reading and new phonological approaches to reading instruction. So, by 2003, in the face of falling literacy levels, the NZ Ministry of Education began to include phonological awareness within its literacy strategies (Thompson, 2003). Anecdotal evidence would suggest that phonological approaches to reading instruction and intervention have not yet been fully embraced at the classroom level in NZ. Research has indicated that this could be in part due to poor teacher knowledge of phonological awareness and how to teach it, meaning that teachers are poorly equipped to apply phonic-based approaches to reading instruction (Carroll, Gillon, & McNeill; 2012).

2.6 The Role of the Speech-Language Therapist in Phonological Awareness

Literacy skills, as with any language-based skill, are part of the SLT's role within the school setting. Research has shown that the SLT's specialist and superior knowledge of phonological awareness (Carroll et al., 2012; Spencer, Schuele, Guillot, & Lee, 2008; L. Wilson, McNeill, & Gillon, 2015) is essential in the literacy context, especially given the evidence that NZ teachers' knowledge of phonological awareness, like those of teachers in other countries, is not sufficiently adequate to support literacy acquisition or failure (Carroll et al. 2012; Fielding-Barnsley, 2010; Stainthorp, 2004). The New Zealand Speech-language Therapists' Association (2012) *Scope of Practice* document highlights that SLTs can and should be called on to intervene where a child is experiencing risks related to literacy achievement. Yet it would seem that, for many reasons, SLTs' knowledge of phonological awareness and its importance to reading and spelling is under-utilised by the school system in NZ. This is surprising given the results of local research which showed that SLTs directly coaching teachers to implement phonological awareness programmes had positive results for the literacy outcomes in classrooms (Carson, Gillon, & Boustead, 2013; Wilson et al, 2015).

2.7 Phonological Awareness in Conceptual Models of Reading

SLTs involved in literacy may approach assessment and therapy by using a model such as the simple view of reading (SVR) (Gough and Tunmer, 1986) which highlights the importance of decoding, and hence phonological awareness skills in the reading process. The SVR proposes a simple equation to understand reading; Reading comprehension = Decoding x Language comprehension. Gough and Tunmer developed the SVR as a critical response to the dominating whole language approach and to reposition phonological skills as necessary to the reading process. In the years after its development, the SVR was widely embraced in the reading science literature but was criticised for not considering the cognitive elements involved in reading acquisition. Tunmer and Hoover (2019) later acknowledged that, whilst the SVR model is very simplified, it would be unwise to view the cognitive subskills required for successful reading acquisition as simplistic, and consequently developed a more comprehensive model (Tunmer & Hoover, 2019; see Figure 1). In the 2019 model, phonemic awareness is again a foundation skill for word recognition and subsequent reading comprehension but with recognition of contributing cognitive skills to the process. Similar conceptual models to the SVR explain the complex process of acquiring reading, such as the reading rope (Figure 2), cognitive foundations for learning to read (Figure 1) and the sources of literacy (Figure 3). All these models acknowledge the elements necessary for reading acquisition; endorsing the concept that learning to read is a multifaceted, non-linear and complex process. But of particular interest to the current study is that all of these models mark a definitive place for phonemic and/or phonological awareness in acquiring reading fluency. Figure 4 graphically illustrates how phonologically-based decoding deficits, compared to intact language comprehension skills, are central to a diagnosis of dyslexia. In Figure 3, speech pathologist and researcher Dr Ros Neilson goes a step further and includes “speech sounds” in the development of phonological and phonemic awareness skills. Intact hearing is necessary to listen to speech sounds and consequently develop phonological awareness (Bowers et al., 2014; James et al., 2005; Nittrouer & Caldwell-Tarr, 2016). Hearing scientists could suggest including the ability to hear clearly and/or process auditory information as a foundation skill but these are not included in these models of reading acquisition.

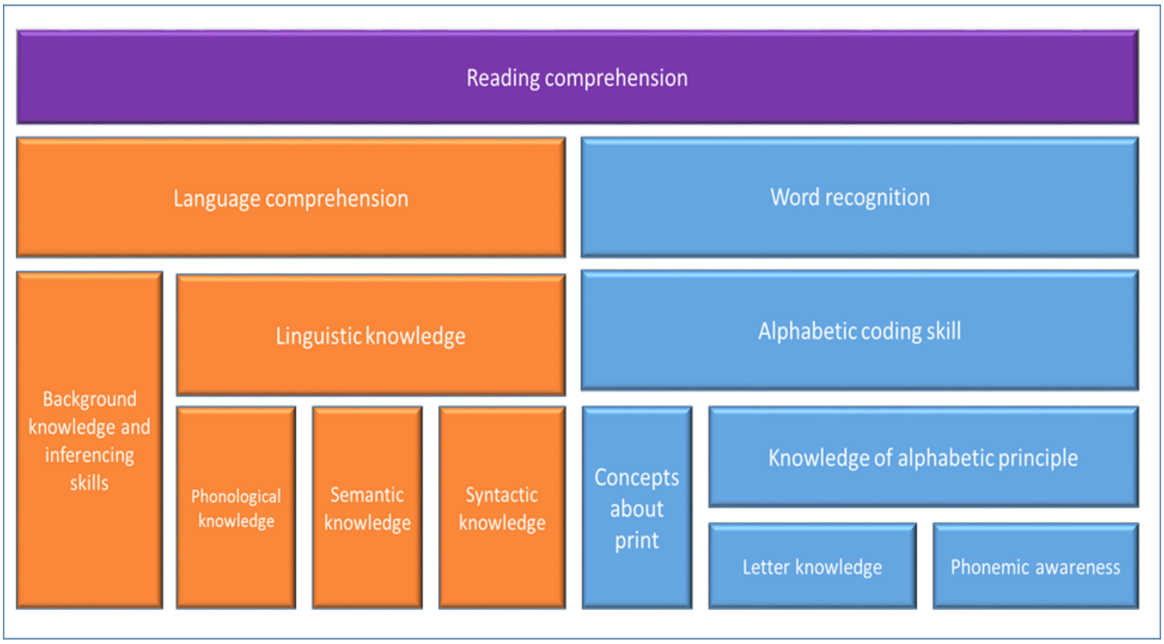

Figure 1. Cognitive foundations of learning to read. (Adapted from Tunmer & Hoover, 2019).

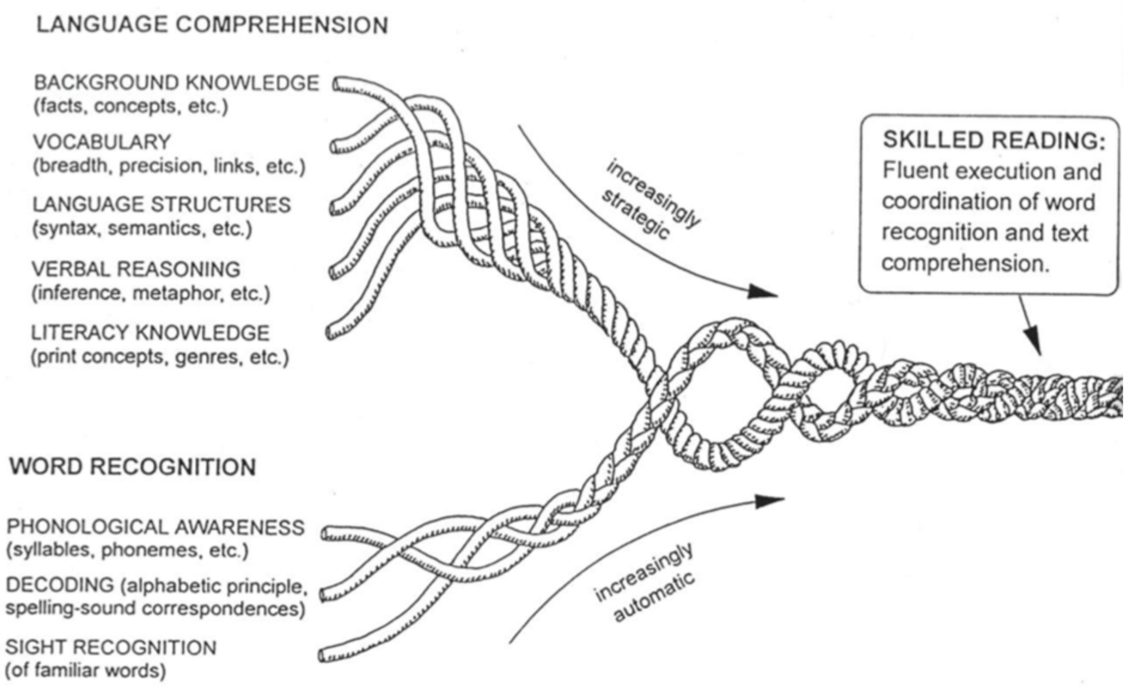

Figure 2. The "reading rope" strands of early literacy development. Source "Connecting Early Language and Literacy to Later Reading (Dis)Abilities: Evidence, Theory, and Practice," by H. S. Scarborough, 2002, in S. B. Newman & D. K. Dickinson (Eds.), *Handbook of early literacy research*, p. 98, New York, NY: Guilford Press. Copyright 2002. Retrieved from https://dyslexiaida.org/scarboroughs-reading-rope-a-groundbreaking-infographic/

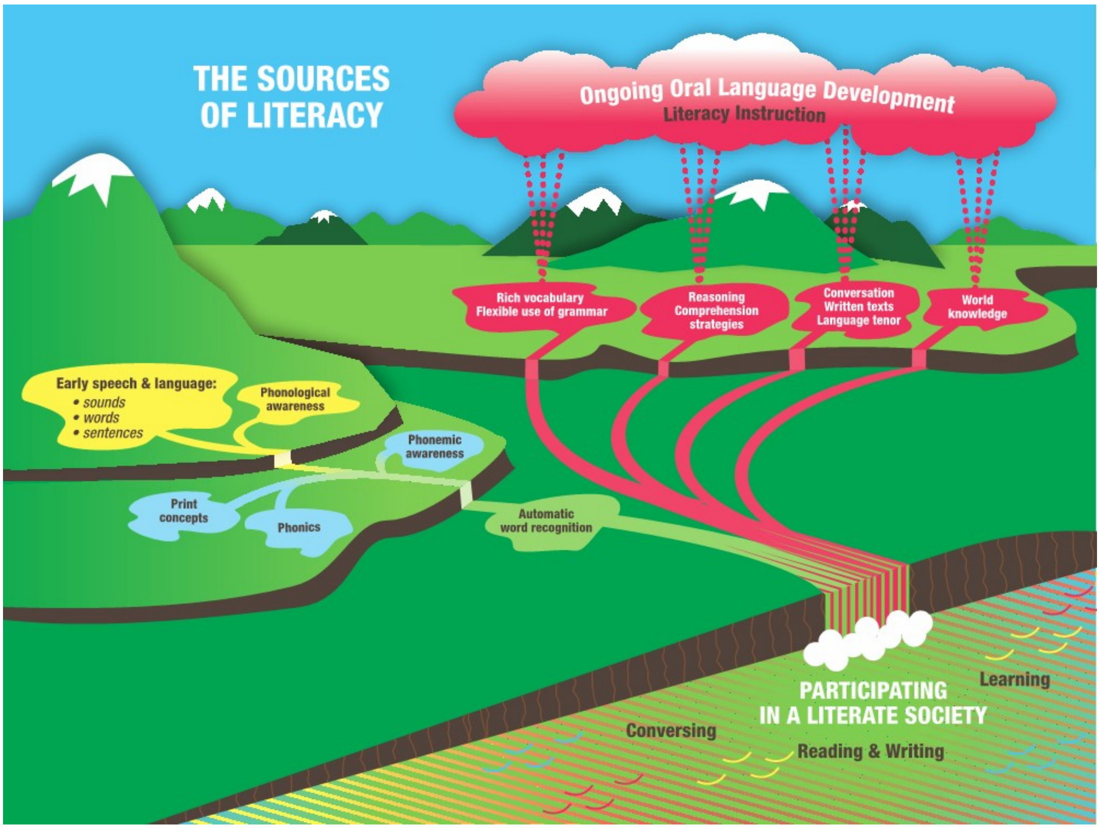

Figure 3. The sources of literacy (2016). Printed with permission from Ros Neilson.

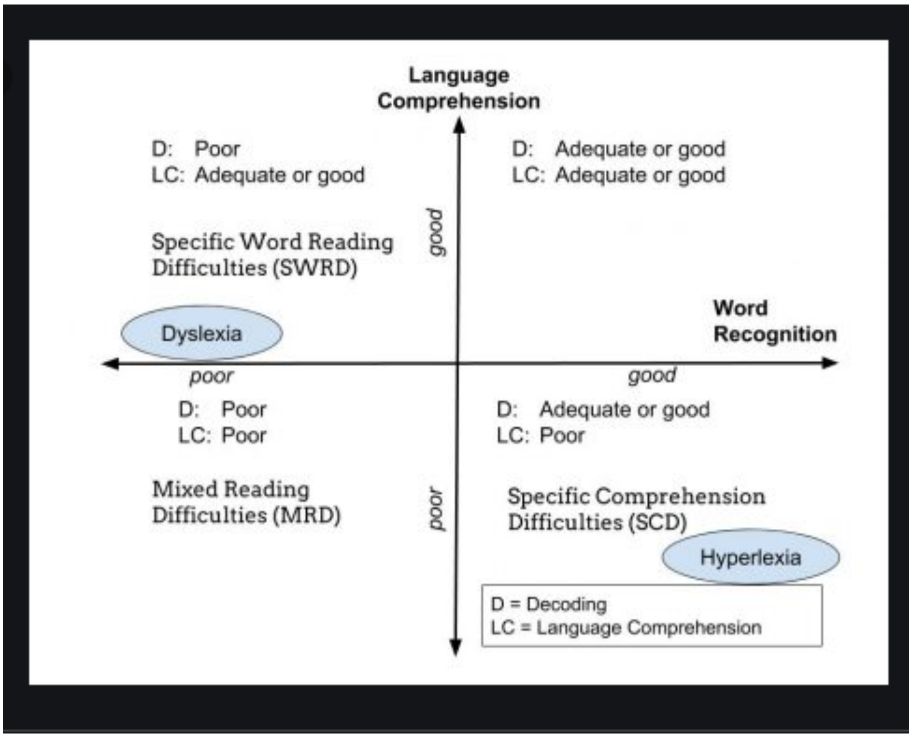

Figure 4. A model showing the role of language comprehension and word-recognition skills in reading disorders. Adapted from *The Simple View of Reading* (Gough & Tunmer, 1986).

CHAPTER 3. Dyslexia

Dyslexia is used in the public arena to describe all manner of problems experienced with reading and spelling. The overuse and misrepresentation of the term dyslexia can lead to confusion about how to assess and manage it. Therefore, the current study defines children with dyslexia, according to the SVR, as having deficits primarily in phonological skills which inhibit their reading ability (Gough & Tunmer, 1986).

3.1 Dyslexia Explained

Dyslexia is a specific learning disability with genetic and neurobiological origins; it is both heritable and familial (Shaywitz, 2003) and commonly characterised in research and practice by the inclusion criteria of difficulties with decoding, accurate and/or fluent word recognition, and poor spelling (Ramus, 2003; Snowling & Stackhouse, 1996). It is generally accepted in the literature that the decoding difficulties in dyslexia typically result from a deficit in the phonological component of language, and are present with relatively intact comprehension skills (Catts & Kamhi, 2005; Gillon, 2018; Gough & Tunmer, 1986). Unlike wider diagnostic terms used to describe reading problems, such as reading disorder, a dyslexia diagnosis should only be made in the presence of normal cognition, motivation and schooling support (Shaywitz et al., 1999). The literature is less clear about the relationship between developmental language disorder (DLD) and dyslexia because phonological ability is by definition a language-based skill (Adlof & Hogan, 2018). However, in general phonological-core deficit based theories of dyslexia tend to exclude the presence of wider semantic or pragmatic language disorders.

3.2 The Prevalence of Dyslexia

Differing criteria for describing and defining dyslexia in research and practice means that the reported incidence rate can vary from as little as 4–6% of the population (Schulte-Körne & Remschmidt in Neef, Schaadt & Friederici, 2016) to as high as 20% (Shaywitz et al., 1990). The NZ Ministry of Education website (www.inclusive.tki.org.nz/guides/dyslexia-and-learning/understanding-dyslexia/) states a 10% dyslexia prevalence rate for children in NZ schools; a prevalency which is consistent with other countries (Sedaghati, Foroughi, Shafiei, & Mohammad, 2011). It is important to recognise that whilst dyslexia is commonly revealed at the age of reading acquisition (the school-aged child), it is a lifelong difficulty. In fact, contrary to popular belief, preschool children can often exhibit early warning signs of dyslexia in the form of a phonological speech disorder and/or poor phonological awareness (Boets et al., 2011; Gillon, 2018; Snowling & Stackhouse, 2006). Children experiencing dyslexia often have comorbidities, such as other learning disorders. Not surprisingly, but of special interest to SLTs, is that dyslexia commonly coexists with DLD (Bishop, Snowling, Thompson & Greenhalgh, 2017).

3.3 Dyslexia in New Zealand Schools

In keeping with the strengths-based philosophical approach dominant in many NZ schools, a diagnosis of dyslexia is not usually made by school staff but by a professional outside the classroom, such as an educational psychologist utilising cognitive and academic profiling tests with normed and standardised scoring systems. These test sessions will commonly include a test of phonological awareness. In comparison, NZ schools use curriculum-based literacy measures to determine the level within which children fall for each curriculum subject (e.g., reading, writing, and maths). It is common in NZ, but depends on the school, for a child's progress to be measured using a combination of comparison with their own progress in a subject, and a nationwide average. Historically, struggling readers were commonly referred to a Reading Recovery programme, as a preferred approach to ameliorating dyslexia, within their first year of school (Gillon, 2018). NZ schools are individually self-governed, so the range of remedial reading resources a school can access is dependent, in part, on the approach they consider best for their learners. The Ministry of Education provides information for teachers on dyslexia primarily focused on how to adapt the learning environment to support children with the condition in the classroom. Dyslexia is a phonologically based reading problem and reading recovery lacks phonologically focused strategies, calling into question the benefit of this approach for children with dyslexia.

3.4 What Science Tells Us About Dyslexia

Dehaene and his team of neuroscientists (2011) joined the call for educationalists to look to the science which strongly supports the role that the auditory, phonological and language centres play in directing the reading process. The advent, in more recent times, of less invasive brain imaging techniques such as functional MRI (fMRI) scans has seen the role of neuroscience strengthen our understanding of neurophysiological workings behind reading. We are now able to 'observe' the roles of the visual, auditory and language centres involved in reading acquisition via fMRI scans (Dehaene et al, 2011 and auditory evoked-potential research (Noordenbos, Segers, Serniclaes, Mitterer, & Verhoeven, 2012; Sharma et al., 2009). In 2001, Haist et al. (2001) found that regions in the auditory cortex are active even in silent reading tasks, highlighting the crucial role of auditory processing in visual word recognition. Using auditory evoked potentials, Sharma et al. (2006) found electrophysiological evidence of difficulties in auditory processing of non-words (suggestive of phonological awareness problems) in children with reading disorders. In 2009, Blau, van Atteveldt, Ekkebus, Goebel, and Blomert's fMRI research showed adult dyslexic readers' brains are under-activated in the superior temporal cortex, a brain area responsible for the integration of letters and speech sounds. This finding suggested that reduction in the audiovisual integration of the phoneme to the grapheme is directly associated with a more elemental deficiency in auditory processing of speech sounds, which in turn predicts performance on phonological tasks. Neuroscience continues to suggest that the basis of some dyslexic features could in fact prove to have an auditory processing foundation and more research is required in this area (Snowling & Stackhouse, 2006).

3.5 The Auditory Deficit Theory of Dyslexia

Some studies in the hearing sciences theorise that phonological awareness hinges on auditory processing to identify and manipulate phonemes (Boets et al., 2013; Hornickel, Zecker, Bradlow, & Kraus, 2012; Kuppen, Huss, Fosker, Fegan, & Goswami, 2010). The auditory deficit theory of dyslexia maintains that neural auditory stability is key to phonological awareness development (Boets et al., 2013). Corruption or disruption of the neural transfer from auditory signal to auditory representation leads to fuzzy phonological representations, causing phonological awareness and hence literacy problems (Ramus, 2003; Sharma et al., 2006; Tallal, 1980). An increasing body of research asserts that in order to acquire reading successfully, children require neural auditory stability (Bonacina et al, 2019) and that people with dyslexia have central auditory deficits which cause difficulty storing and/or retrieving the phonological representations needed to learn to read (Hornickel et al., 2012; Veuillet, Magnan, Ecalle, Thai-Van, & Collet, 2007). This hypothesis is supported by studies which have shown that struggling readers require greater differences between sounds in order to mentally categorise them (e.g., Richardson, Leppänen, Leiwo, & Lyytinen, 2003). Whilst caution is still practised by most researchers when suggesting a causative link, studies do show a strong correlation between reading disorder and APD (Hämäläinen, Salminen, & Leppänen, 2013; Sharma et al., 2009). Kuppen et al. (2011) suggested that, on their measures of auditory thresholds at least, there seemed to be a reciprocal causal relationship between progress in reading and auditory perceptual skills. They found, like similar longitudinal research by Corriveau, Goswami, and Thomson (2010), that auditory processing of 'rise time', predicts the development of both phonological and literacy abilities in preschool children. Kuppen et al. (2010) were unsure if intact auditory processing *enables* normative phonological development, or whether good phonological skills in fact enhance auditory processing abilities. Sharma et al.'s recent research (2019) found, from their wide-ranging battery of tests, that the only measure which appears to have a relationship with reading and spelling ability in school-aged children was the frequency pattern test (FPT).

3.5.1 Exploring the auditory deficit theory.

The controversial role that auditory processing plays in reading acquisition and failure is highlighted by mixed research findings. A unifying feature of most of the studies on auditory processing and perception (of both speech and non-speech sounds) in relation to reading difficulties is that only some, but not all, individuals with dyslexia perform significantly differently from typically developing readers. Farmer and Klein's 1995 review of the literature revealed considerable evidence for auditory deficits in stimulus individuation tasks (e.g., gap detection) and temporal order judgements (TOJ). Boets et al. (2011) found school-aged children with dyslexia had impaired speech perception, speech-in-noise perception and phonological awareness in kindergarten. A systematic review of behavioural and event-related potential/field evidence in APD by Hämäläinen et al. (2013) found that children with dyslexia do have some kind of auditory processing deficits, but they could not draw a causative link between the disorders. The literature is unclear whether children diagnosed with APD have reading problems related to comorbid attention and/or language rather than auditory processing problems (Rosen, 2003, Sharma, Purdy, & Humburg, 2019). In an effort to predict the elements which would impact on school performance (including reading success) Watson et al. (2003) assessed 160 children starting school in Indiana (USA) with an auditory processing test battery but found that, for this sample at least, auditory processing of speech and reading achievement were virtually unrelated independent skills. Sharma et al. (2018), although not able to associate many of the measures used in the current APD battery with reading and spelling outcomes, found that the FPT impacted reading and spelling measures. The FPT indicated a variance of 11% in non-word reading, 10% in non-word spelling and 4% in regular-word reading. Sharma et al. attributed the difference between regular and non-word results to the auditory aspects of the task, because regular words are more likely to be part of the child's lexicon, so the reading and spelling of them was assisted by semantic links, unlike non-words, which require accessing of poor PGC via the imprecise phonemic representations they had formed possibly due to APD. Sharma et al. (2018) conceded that the FPT involved both auditory (frequency discrimination, temporal processing and linguistic labelling) and cognitive skills (sustained attention and memory) which could account for its relationship to reading and spelling ability. In recent research using AP treatment methods (of their own design), Barker and Hicks (2020), improved age-equivalent reading scores in school children with learning difficulties. They believe this suggests underdeveloped AP (specifically with dichotic listening and/or tonal-pattern processing) could be responsible for poor reading ability. It appears that, for much of the research, differences in auditory perception could not offer a single causal explanation for a presentation of dyslexia, so there is no firm evidence for a causal relationship (Boets, 2011). Whilst the auditory deficit theory is an attractive proposition, most literature at this stage accepts a correlative relationship only between AP and reading ability (Ramus, 2002; Sharma et al., 2009).

3.5.2 Is poor phonemic awareness caused by auditory processing disorder?

Franck Ramus (2003), after conducting research on adults with dyslexia, hypothesised that for at least a subset of children with APD, their dyslexia was caused by what he called “a phonological access” auditory processing problem (see also Farmer & Klein,1995; Tallal et al., 1993). Despite discussions about the phonological awareness problems existing in children with APD, there are few studies which actually assess the phonological awareness of children with APD (Appendix A). Burns (2013), stated that auditory processing, language and reading impairment are neurologically entwined, and children with APD are likely to have poor phonological processing because of difficulties discriminating speech sounds (Raschle, Stering, Meissner, & Gaab, 2014), and that, in fact, phonemic awareness could be the point of interception between auditory processing and dyslexia, such as Figure 5illustrates. The hearing sciences focus on information from research that children with dyslexia exhibit difficulty processing rapid spectro-temporal characteristics of phonemes (Burns, 2013), difficulties with slow auditory sampling (Goswami, 2012), and show poor consistency of the auditory brainstem response to speech stimuli (Hornickel et al., 2012). There is some evidence to support “slow rise time” as a predictor of literacy and phonological awareness abilities (Corriveau et al., 2010; Kuppen et al., 2011). In addition, disorders of auditory timing detection have been found to be related to disorders of auditory discrimination, reading and language (Farmer & Klein, 1995; Muluk, Yalçınkaya, & Keith, 2011; Walker, Hall, Klein, & Phillips, 2006). Walker et al. (2006) found that children with dyslexia had more difficulty recognising auditory patterns of differing frequencies and temporal durations for tonal stimuli. De Martino, Espesser, Rey, and Habib (2001), using a small sample size of older school-aged children with dyslexia, found they performed poorer in a test of temporal processing (temporal order judgement) than control participants. In addition, De Martino et al. found that slowing the rate of speech-sound presentation improved children's temporal processing performance, a result which correlated with tasks of phonological awareness (phoneme deletion, rhyme judgement). According to De Martino et al., these findings lend weight to the theory of a relationship between phonological awareness and temporal processing. Sharma et al. (2006), in a larger cohort (n=23), found that children with reading disorders, in comparison to a control group without reading disorders, exhibited deficits in identifying frequency patterns (i.e., FPT) in addition to absent or smaller cortical responses (/ga/ evoked mismatch negativity). In essence, it appears that rapid auditory processing, at cortical and subcortical levels, is a component of phonological awareness and, as such, problems in this area are a possible causative factor in some children with language problems and, due to the relationship between language and reading, reading problems as well (Burns, 2013). Researchers surmise that the non-segmental, multi-layered nature of the speech signal makes it difficult for individuals with dyslexia to distinguish the features of the actual sounds produced and/or perceived and may require greater differences between sounds in order to categorise them (Richardson, Leppänen, Leiwo & Lyytinen, 2003; Richardson & Lyytinen, 2014).

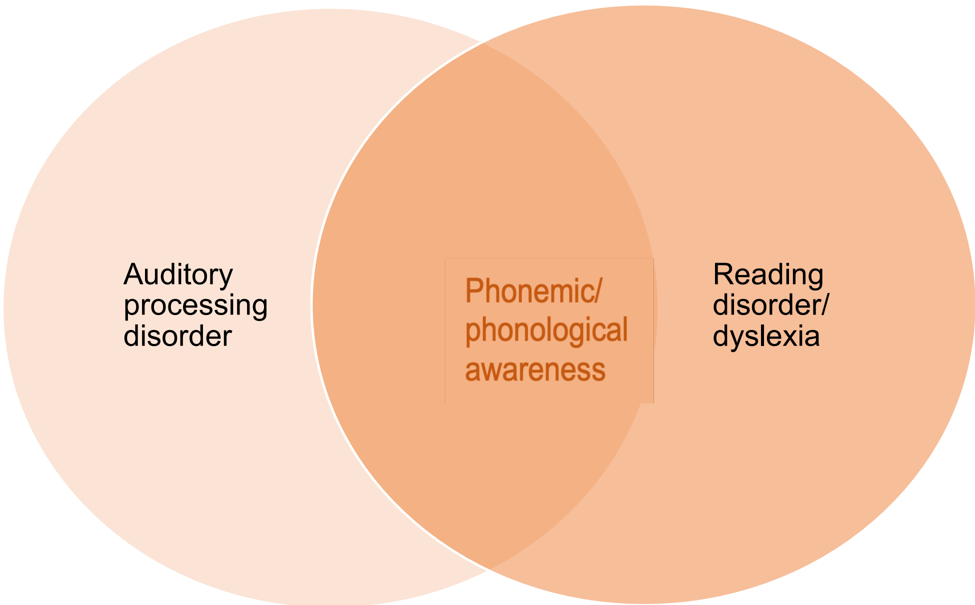

Figure 5. Phonemic awareness as a proposed intersect between APD and reading disorder/dyslexia.

3.5.3 Limitations to the auditory deficit theory of dyslexia.

Psychoeducational sciences maintain that reading involves complex multifactorial cognitive processes and is not a linear, hierarchical or sequential model stemming from an auditory signal. That auditory perception is the root cause of dyslexia remains debatable. The auditory deficit theory of dyslexia is limited by the following points: 1) the inconsistency of defining auditory processing and/or auditory perception deficits and how to measure them (Mody & Studdert-Kennedy, 1995; Moore, Ferguson, Edmondson-Jones, Ratib, & Riley, 2010; Wilson, 2019); 2) the inconsistency of defining dyslexia, which is often used as an umbrella term for all reading disorders, and how to measure it (Snowling & Stackhouse, 2006); 3) the cognitive and maturational variables involved, and not always accounted for, in testing children's auditory process (Kuppen et al, 2011; Wilson, 2019); 4) confusion caused by the high rate of comorbidities with both APD and dyslexia; and 5) problems with defining the terms of reference for both disorders (Gillon, 2018; Wilson, 2019). Mody and Studdert-Kennedy (1995), among others, discounted the auditory deficit theory by stating the phonological impairments in dyslexia are speech specific and language based, not auditory in origin (Snowling & Stackhouse, 2006). In opposition to the auditory deficit theory of dyslexia, which claims children with dyslexia struggle to perceive smaller units of sound, some research has indicated that individuals with dyslexia actually perceive *smaller* differences in speech sounds than individuals with typical reading (Bogliotti, Serniclaes, Messaoud-Galusi, & Sprenger-Charolles, 2008). In addition, in a recent study of Chinese children, Zhang and McBride-Chang (2014) found a correlation between phonological awareness ability and auditory perception ability as measured by categorical perception of consonants, categorical perception of lexical tone, and lexical tone discrimination. It could be that these findings are suggestive of a more symbiotic and bidirectional relationship between auditory processing and phonological awareness.

CHAPTER 4. Auditory processing disorder

There is still controversy about the definition, terminology, assessment and management of APD (Cacace & McFarland, 2008, 2014; Moore et al., 2010; Vermiglio, 2014). Half a century of research and debates include whether APD is, in fact, a separate diagnostic entity and exactly which functional difficulties may or may not be attributed to it. There do seem to be many possible and variable, but generally vague, functional presentations associated with APD: from poor listening in the presence of noise, poor auditory memory, reduced comprehension, slow speech processing, through to dyslexia/reading disorders. I acknowledge these controversies but focus on APD and its possible relationship with dyslexia. Knowledge of auditory processing and APD is specific to audiologists and not always accessible to allied professionals such as SLTs. The neurophysiological and electrophysiological processes involved in processing the acoustics of speech are a deeply technical and specialised area of audiological science and are outside the scope of this study. But a brief and rudimentary description of auditory processing will follow, with reference to Figure 6 which illustrates the auditory anatomical features in relation to hearing loss.

4.1 Auditory Processing of Speech Explained

The manner by which our central auditory nervous system (CANS) turns electrical impulses into meaningful sound units for cognitive purposes, occurs beyond the peripheral hearing system (see Figure 6), and is called auditory processing. Simply put, it is the way in which the brain interprets sound. Acoustically, speech sounds are physical events that vary in frequency (pitch), are distributed in time and require neural encoding. The manner by which the brain translates acoustic signals into meaningful speech relies somewhat on how the central nervous system interprets the spectral and temporal aspects of phonemes: the intensity, pitch, tonal range and the timing of the acoustic signal. During the pre-linguistic stage, a pressure wave (sound) enters the peripheral hearing system through the ear canal to strike the tympanic membrane (ear drum), resulting in vibrations through the inner ear. At the level of the cochlea, kinetic energy (vibration) is converted into electrical impulses which set in motion a series of neural responses beginning in the brainstem and moving up through the afferent auditory network of neurons to the auditory cortex (Stach, 2010). Cues from both ears locate and process sound with the acoustic signal being represented both spatially and temporally in the cochlear. The basilar membrane of the cochlear is tonotopically organised, and filters different frequencies of sounds from its base to its apex. Speech sounds are in part formulated by the sequence of the evoked spike discharges (Eggermont, 2015), the neural firing rates in time with the sound's frequency. There are specific neurons along the auditory pathway that code for timing and level (loudness) differences. The central auditory pathway consists of multiple stages of processing, including the recruitment of other neural regions once the signal reaches the auditory cortex, and inter-hemispheric translation of information across the corpus callosum. A breakdown at any stage, involving either or both frequency and temporal information, can result in auditory processing deficits. Auditory processing ceases at the linguistic stage of processing when acoustic signals of speech are transitioned into meaningful units or *phonemes*. At the linguistic stage, language-processing regions such as Wernicke's area (speech comprehension) and Broca's area (speech production) in the left temporal lobe of the brain are recruited to make sense of these units. The auditory temporal aspects of sound which underlie a phonemic unit are present in the carrier frequencies in the sound waveform. For research purposes, scientists in audiometry use neurologic imaging tests such as auditory brainstem response (ABR) and cortical-evoked potentials to measure auditory brain activity. For practical and economic clinical reasons, audiologists in the field use *behavioural* assessments (so called because they rely on the client's response to stimuli) to measure auditory processing. Bonacina et al. (2019), using ABR, found auditory neural stability, an index of how accurate a brain is in coding a speech stimulus over repeated trials, was specifically related to phonological awareness ability (measured by two subtests of the CTOPP-2) but only up until the early school years. Bonacina et al.'s findings support the theory that the consistency with which a speech sound is auditorily processed each time it is heard, facilitates phonological awareness.

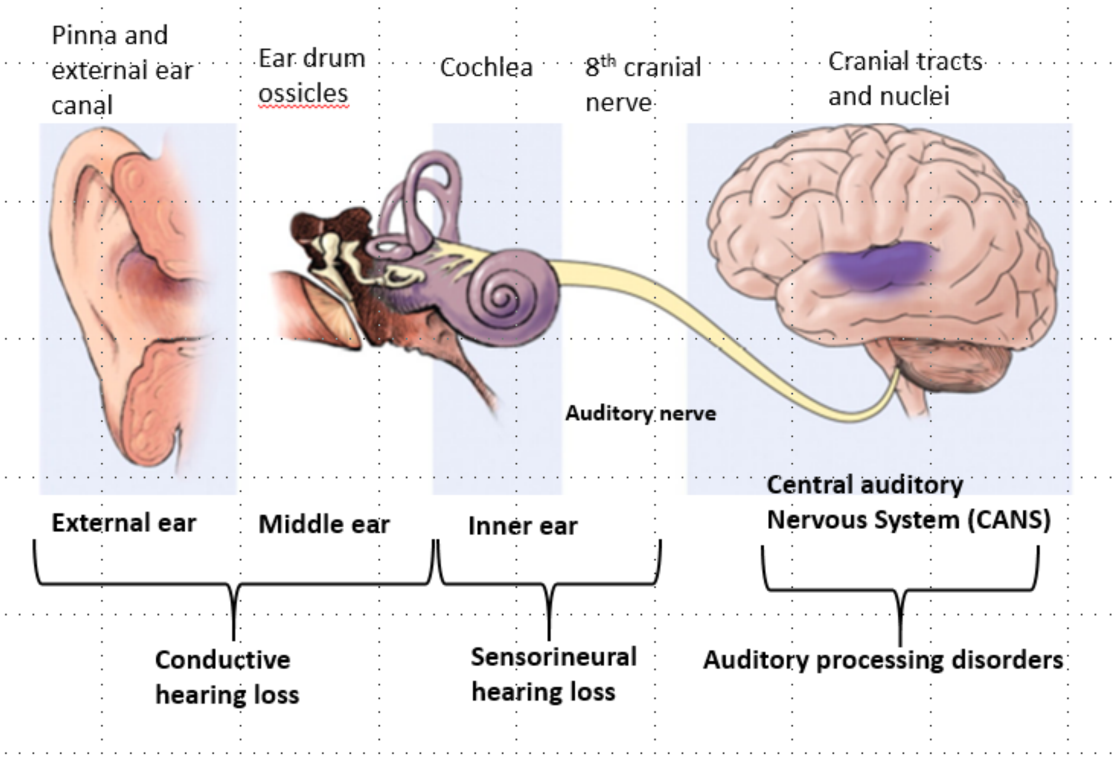

Figure 6. Anatomy of the ear and sites of hearing loss. (Adapted from Bance, 2007).

4.2 Background to Auditory Processing Disorder

Auditory perceptual difficulties in the presence of normal peripheral hearing, have been reported in audiology, speech-language therapy and psychology publications since the 1950s (Katz, Chasin, English, Hood, & Tillery, 2015). Clinicians had identified that, despite normal hearing, some clients, after a neurological event, still presented with difficulty listening and understanding speech. Early research interest in auditory processing difficulties was primarily with adults who had brain lesions of an aphasic nature. By the 1960s, educational communities had begun to recognise similar listening difficulties in children, despite the absence of a neurological event, presumably due to developmental factors. The research of Paula Tallal (1976) is often quoted as the defining point when APD was identified as a separate diagnostic phenomenon in children. Tallal (1976) described the auditory processing deficits primarily as an inability to discriminate rapid changes in pitch of tones (i.e., temporal processing deficits). After much research, discussion and debate, in 1992, The American Speech-Language-Hearing Association (ASHA) became one of the first professional bodies to recognise and describe CAPD or the now most often used term APD. Other international professional organisations for audiologists and SLTs have followed suit over the years. However, clarification about the nature and presentation of APD continued to be sought into the new millennium with Wilson, Heine, and Harvey (2004) stating that there were too many varied definitions among professional bodies (ASHA, 2005a; American Academy of Audiology [AAA], 2010; BSA, 2011, cited in Tomblin, 2015). The status of APD remains controversial in the wider community, but has recently been recognised as a disorder by the World Health Organization (2018) and added to the International Classification of Diseases (ICD) the international standard for defining and reporting diseases and health conditions.

4.3 Auditory Processing Disorder Explained

Geffner and Ross-Swain (2019) described APD to be a modality specific “impairment with the brain’s ability to recognise and process sound effectively into words and language” (p. 577) in the presence of normal peripheral hearing. Deficits in auditory processing and hence APD can occur at any of the levels at which the brain translates an acoustic signal into meaningful speech. It is widely accepted that APD refers to difficulties in the perceptual processing of auditory information in the central nervous system, or, more specifically, as a neurobiological activity (measured by recording electrophysiologic auditory evoked potentials) that underlie the manner in which the CANS processes sound. Deficits of auditory processing occur in how the nervous system interprets the intensity, pitch, tonal range and the timing of the acoustic signal. The amplitude and frequency modulations of the carrier waveform (including starts, stops, and gaps) are of particular interest to hearing scientists because of the suspicion that problems at this level of a child’s perception may result in dyslexia (Burns, 2013). Table 3 describes some of the terms used by audiologists to describe auditory processing deficits. The AAA (2010) practice guidelines for the diagnosis, treatment and management of children and adults with APD use the strong link between lesions of the CANS and deficits in electrophysiological and behavioural measures of auditory skills as support for the existence of APD. Positive findings from electrophysiological tests measuring the brain’s auditory responses to relevant and irrelevant phonetic stimuli (bypassing behavioural measures), increase the likelihood of an audiological interrelationship to reading ability (Noordenbos et al 2012; Sharma et al., 2009). Removing the psychological variables of cognition, behaviour and attention from the diagnostic testing of APD is considered a strength for the assertion of APD as a separate diagnostic entity.

Table 3

Auditory Processing: Descriptive Term and Corresponding Disordered Ability (Adapted from ASHA, 1996; Bellis, 2003).

Descriptive term	**Disordered auditory processing ability**
Sound localisation and lateralisation	Ability to identify and localise where a sound has occurred in space.
Auditory discrimination	Ability to automatically distinguish one sound from another.
Auditory pattern recognition	Ability to determine differences and similarities in sound patterns.
Temporal processing	Ability to process acoustic stimuli within time. Includes terms such as: - Temporal masking: the ability to muffle or override weaker phonemes before or after stronger phonemes (commonly called forward or backward masking). - Temporal resolution: the ability to perceive fast-changing signals. - Temporal integration: the ability of both ears to work together to sequence and integrate sounds. - Temporal ordering: the ability to process durational patterns in a sequence
Speech-in-noise	The ability to recognise speech or other sounds in the presence of competing noise
Degraded speech	The ability to perceive a signal in which some information is missing e.g., high or low frequencies are extracted, or the signal are compressed in time. Auditory performance reduces as acoustic signals degrade.

4.4 How Does Auditory Processing Disorder Present?

There is much debate about some of the presenting conditions associated with APD, but there is general agreement about one of the most common presenting conditions, which is speech-recognition problems in the presence of background noise (Neijenhuis, de Wit, & Luinge, 2017). However, it can be difficult to separate what appears, on the surface, to be an obvious deficit in auditory processing, from underlying difficulties of language and cognition (Brenneman et al, 2017; Sharma et al., 2009; Sharma et al., 2018). Within the diagnosed population of children with APD, there are varying functional presentations. Audiologists commonly describe APD by naming some of the presenting conditions which are highlighted through failing tests within the APD test battery. An example is amblyaudia, a “neural integration” type disorder of abnormal asymmetry between the two ears revealed by failing binaural integration tests. It is thought that amblyaudia can cause a child to struggle with functional tasks involving attention, working memory and/or language. Another condition presenting within APD is a *spatial processing disorder* (SPD), a complex audiological phenomenon which, put simply, describes a condition where the ears do not adjust in time and intensity to the arrival of the acoustic signal due to a breakdown in the auditory integration system (Cameron, Dillon, Glyde, Kaufaman, & Kania, 2014). In their recent cluster analysis of 90 school-aged children diagnosed with APD, Sharma et al. (2019) identified four subgroups of APD: children with (1) global deficits, (2) poor auditory processing with good word reading and phonological awareness skills, (3) poor auditory processing with poor attention and memory but good language skills, and (4) poor auditory processing and attention with good memory skills. These subgroups explain the variation in areas of difficulty observed across different studies in the literature and the heterogeneous nature of APD (Bellis, 2007), highlighting the need to assess a range of skills in children with suspected APD. Less than specific terminology (e.g., perceive, integrate, process) to describe the abilities in Table 3 means cognitive functioning is often difficult to separate from tasks of auditory processing. In fact, there are studies that have found shared variance with APD and cognitive and language abilities (Brenneman et al., 2017; Moore et al., 2010).

4.5 The Prevalence of Auditory Processing Disorder

The NZ prevalence of APD is estimated at 6.2% of the child population or approximately 54,000 children (Esplin & Wright, 2014). Most recently, and of relevance to NZ, were findings by Purdy et al. (2018) that nearly a third of the Pasifika population they assessed had some evidence of APD. Prevalence may vary across countries and populations, depending on the research and undoubtedly the diagnostic test battery used by the differing studies, with rates as low as 1.96 per 1,000 school-aged children in one American study (Nagao et al., 2016).

4.5.1 Behavioural testing of APD.

The purposes of testing auditory processing are two-fold: (1) to identify the presence of abnormalities in or dysfunction of the CANS and to diagnose APD, and (2) to describe the nature and extent of the disorder for purposes of developing management and intervention programmes for affected individuals (AAA, 2010). This deficit-specific approach to testing focuses on identifying areas to ameliorate and/or *fix* in the auditory system by the pass/fail results of APD tests. When conducting their chosen APD test battery, audiologists examine a variety of auditory performance areas compared to normative data (ASHA, 2005a). Table 4 shows some of the many possible APD tests which could be selected for use by audiologists. In the past, a diagnosis of APD was made when a deficiency in one or more auditory processing tests was found. However, since the updated ASHA APD technical report of 2005, a diagnosis of APD is now recommended when two or more subtests have two or more standard deviations (SD) from the norm, or one subtest has three SDs from the norm (Tillery, Katz, & Keller, 2000). This diagnostic criterion is in keeping with the AAA criteria. It is these ASHA and AAA criteria for diagnosis of APD that are often used in research. Tests selected for APD diagnosis vary between countries, clinicians, clients and research studies, leading to confusion when interpreting results, especially into every day listening settings. An APD test matrix adopted from working parties on APD (AAA, 2010; ASHA, 2005a) shows that an APD diagnosis could have as many as 462 possible pass/fail test combinations (Vermiglio, 2014). Kelly (2007) published the NZ test norms for FPT, CRW, DDT the “most frequently used behavioural tests of APD in New Zealand” (p. 62). Although these tests may be less in favour with the advent of more recent APD measures. A test of phonemic or phonological abilities is not commonly part of the APD test battery, although it is assumed that results from APD tests may suggest phonological awareness problems. It is often unclear to audiologists and SLTs how failing APD tests is connected to phonological awareness problems.

Table 4

A List of Some Common Standardised Behavioural APD Tests. Condensed and adapted from New Zealand Guidelines on Auditory Processing Disorder (Keith et al., 2019)

Test name	**Used to test the child's**	**Reference**
DDT	Dichotic listening	Musiek, 1983
RDDT Right ear	Dichotic listening	Moncrieff & Wilson, 2009
(RDDT Left ear	Dichotic listening	Moncrieff & Wilson, 2009
DWT	Dichotic listening	Moncrieff, 2011
SCAN-3: Competing Sentences Test	Dichotic listening	Keith, 2009
SCAN-3: Filtered words test	Distorted speech	Keith, 2009
SCAN-3: Time compressed sentence test	Distorted speech	Keith, 2009
NU-6 1KHz LPFW words test	Distorted speech	Bornstein, Wilson, & Cambron, 1994
LiSN-S^2	Spatial segregation	Cameron, & Dillon, 2008
RGDT	Temporal processing	Keith, 2000
FFPT	Pitch pattern perception	Musiek & Pinheiro, 1987 Musiek, 1994
SCAN-3: Auditory figure ground at 0dB	Speech understanding in background noise	Keith, 2009
SCAN-3: Auditory figure ground at 8dB		Keith, 2009

4.6 Auditory Processing Within Conceptual Models of Processing

Filippini, Weihing, Chermak and Musiek (2019) correctly asserted that APD is a relatively new audiological concept (<50 years) and as such is strongly influenced by dynamic and evolving theories on diagnosis and treatment. Theoretical frameworks and conceptual models of language are often used by practitioners to understand processing abilities. Models are also used by practitioners to delineate roles and responsibilities (Figure 7) and to illustrate complex physiological, cognitive or psychological processes. One such model is Figure 8 which simplifies the transitive journey of acoustic signals to meaningful linguistic units. Models such as these are used by SLTs to consider the underlying processes needed to communicate effectively and can be useful to illustrate levels of possible breakdown in language, communication and cognitive systems.

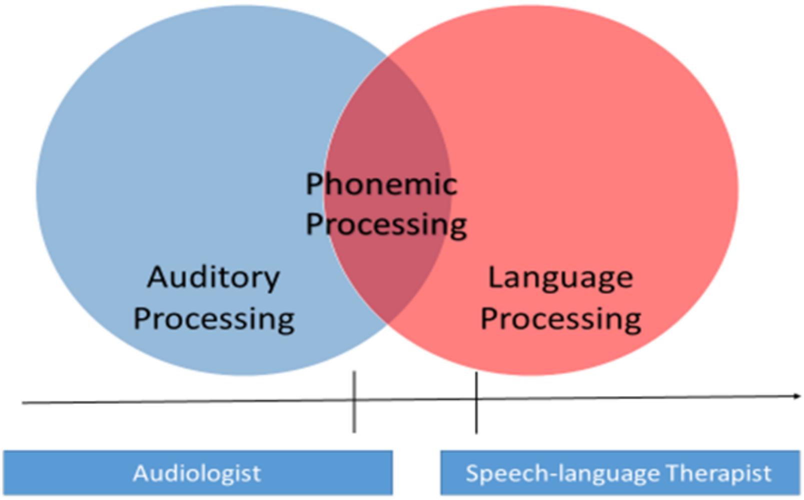

Figure 7. A suggested model of phonemic processing as intersect between auditory and language processing, including professional roles.

Figure 8. A suggested simplified psycholinguistic model of speech processing.

Gail Richard (2017), in a linear hierarchical model of the neurological processing continuum (Table 5) positioned the central auditory processing system as a foundation processing skill to the phonemic and linguistic processing systems. In Richard's model, each level of processing is delineated from the next level by an anatomical referent. As such, Table 5 is an example of a "'bottom-up'" conceptual model of processing in which neural processing is a sound- (data) driven system with the auditory signal determining the higher level/non-auditory factors (such as attention, cognition, language, learning and memory) (McFarland & Cacace, 1997; Wilson, Heine & Harvey et al., 2004). By contrast, "top-down" models of processing argue that higher- level cognitive constraints govern a person's ability to process auditory data. Conceptual models of processing have a place when illustrating complex systems and, at a glance, seem helpful. Confusingly Table 5 shows that both phonemic processing and language processing share the same "'anatomical structure'" and "'type of processing'" calling in to question whether cognitive processing can really be anatomically simplified and hierarchically delineated in such a way. Medwetsky and Musiek (2011), among others, contend that auditory processing is inextricably connected to spoken-language processing and to separate the two is functionally and anatomically untenable. There is opposing research to support both 'top -down' and 'bottom -up' models of processing approaches to assessment and intervention. Hornickel et al. (2012) found that improving auditory processing positively affected phonemic processing; by contrast Johnson, Pennington, Lee, & and Boada (2009) found that processing of phonological representations positively affected the rapid auditory processing abilities of beginner readers. APD researchers, in the main, accept that auditory processing does involve cognitive complexities (ASHA, 2005a; Keith et al., 2019; Sharma et al., 2009) and, as such, assessment and intervention should consider both ‘top -down’ and ‘bottom-up theories. From a practice point of view, guidelines and texts seem to recommend a combination of both top top-down and bottom bottom-up approaches to assessment and intervention as the clinical ideal, rather than one “versus” the other (AAA, 2010; ASHA, 2005a; AAA, 2010; Geffner & Ross-Swain, 2013; Keith et al., 2019; Wilson et al., 2004; Keith et al., 2019). However, it appears that the supposedly opposing conclusions of Hornickel et al. (2012) and Johnson et al. (2009) may both have a place in ~~a~~ nonlinear multiprocessing cognitive models, which accept speech processing is complex and engages auditory, visual, cognitive, and language mechanisms, often simultaneously (Medwetsky & Musiek, 2011; Mossbridge, Zweig, Grabowsky & Suzuki, 2017). A recent argument by Wilson (2019), stated that it is the traditional nominal definition of APD based on deficits in auditory neural networks which limits the functional application of the APD diagnosis. Wilson (2019) is in favour of a new model of APD which describes the characteristics (drawn from theoretically validated models) and harnesses the *concept* of APD (Wilson, 2019). Wilson offered a framework of APD terminology to support this argument, ranging from the child who experiences broad-based “‘listening difficulties,’” through to those with specific APD. Utilising conceptual models of APD is useful when considering the influence that auditory deficits may bring to bear on a child’s functional linguistic presentation. It is safe to say that whilst conceptual models of processing provide a simplified illustration of the interplay between concepts, there is general agreement that it is not realistic to separate the influence that auditory processing skills have on language and cognitive demands for the child within their educational setting (Kamhi, 2011; Richard, 2011).

Table 5

Differential Levels of Processing Including Anatomical Sites

Differential levels of processing	**Anatomical structure or site**	**Type of processing**
Peripheral auditory system	External, middle, inner ear	Auditory acuity, signal reception
Central auditory processing	Central auditory nervous system, auditory nerve through brain stem	Neurological transfer of signal, discrimination of signal’s acoustic characteristics
Phonemic processing	Temporal lobe, Heschl’s gyrus	Discrimination of signal’s phonemic characteristics
Language processing	Temporal lobe, Wernicke’s area and angular gyrus	Discrimination of signal’s linguistic characteristics, attach meaning using language code
Executive functions	Prefrontal and frontal lobe, motor strip	Planning and executing response

From *The Source Processing Disorders*, 2nd ed., by Gail J. Richard, Austin, TX: PRO-ED. Copyright 2017 by PRO-ED, Inc

4.7 Is Auditory Processing Disorder a Separate Diagnostic Entity?

Special working groups have attempted to obtain clarification about the construct of APD (e.g., AAA, 2010; ASHA, 2005a; British Society of Audiology, 2011), but debate continues about the diagnostic criteria for APD, the overlap of APD with other developmental disorders (Sharma et al., 2009), and whether APD exists as a unique diagnostic entity (Cacace & McFarland, 2008; DeBonis, 2015; Moore et al., 2010 Vermiglio, 2014). A clinical or diagnostic entity is a medical term which implies people with the disorder or disease present with a certain degree of uniformity. However, APD, much like many other diagnoses, (for example mild cognitive impairment or developmental language disorder), does not produce a homogenous set of symptoms or people. APD presents with comorbid conditions of learning, language and/or attention disorders (BSA, 2011; Leung, 2017; Sharma et al., 2009; Tomlin, Dillon, Sharma, & Rance, 2015). Some researchers in the field are concerned that children diagnosed with APD may have higher order attention/cognitive problems and not APD at all (Brenneman et al., 2017; Moore et al, 2010). De Wit et al. (2016), in a systematic review of APD, found that there was "substantial overlap" on assessment results from children with APD and specific language impairment, ADHD and dyslexia, and, in reality, the children diagnosed with APD broadly shared the same characteristic as children diagnosed with other developmental disorders. APD is not homogenous in its presentation and, more often than not, presents with comorbidities, as Figure 9 illustrates (Sharma et al., 2009). In fact, some researchers and clinicians suspect auditory processing performance is influenced by a child's related attention, cognitive and behavioural difficulties leading to over-diagnosis and/or misdiagnosis of APD (Moore et al., 2010). Tomblin et al. (2015) are among researchers who reinforce that an important caveat to any diagnosis of APD must be the contribution which the child's cognitive, or top-down, processing skills play in not only the assessment findings, but in the ability of the child to participate in the test battery. It would be fair to say that although APD is attracting increasing interest and recognition as a clinical entity among clinicians in the field, and scientific organisations throughout the world, there is ongoing debate regarding its diagnosis and management. A great deal of this debate is based on rejecting currently used diagnostic auditory processing test batteries (even though they are the best available) because they are not proven as gold standard (Vermiglio, 2014). The lack of clarity surrounding APD, its relatively new presence as a diagnostic category, and the use of multiple behavioural tests involving cognitive skills, mean defining APD as a separate diagnostic entity is debated in the literature.

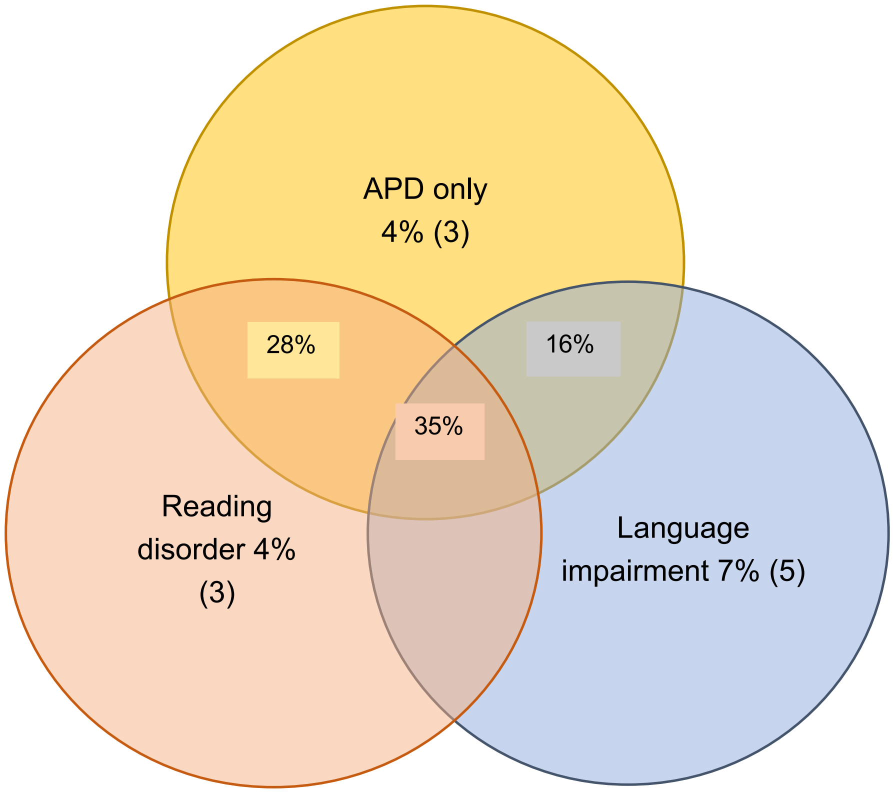

Figure 9. APD and comorbidities of reading disorder and language impairment. (Reprinted with kind permission from Sharma et al., 2009).

4.8 Testing for the Diagnosis of Auditory Processing Disorder: A Brief Background

Diagnosis of APD is typically made on the basis of performance on behavioural auditory tests (Table 4). Auditory processing is diagnosed when there is a mismatch between peripheral hearing ability (which is typically normal) and ability to interpret or discriminate sounds in a range of APD tests. Despite queries about the ecological validity of these tests, they continue to be used clinically to diagnose APD (de Wit et al., 2016 Kamhi, 2011; Richard, 2011). Most diagnostic behavioural tests require a child to be at least 7 years of age due to neuro-maturation of the CANS (Geffner & Ross-Swain, 2019). In addition, testing children younger than 7 has been avoided due to the verbal and attention requirements of the tests. However, the recently released *New Zealand Guidelines on Auditory Processing Disorder* (Keith et al., 2019) suggest the use of tests normed on children younger than seven are available and encourage the audiologist to use clinical judgement to preliminarily diagnose APD in younger children. The literature in the hearing sciences states that both behavioural and electrophysiological tests (CAEP/ABR) can be used to diagnose APD (Geffner & Ross-Swain, 2019). Using CAEP to measure the auditory brainstem response to complex sounds in the clinical setting is, in reality, currently economically unfeasible. Behavioural APD tests have often been adapted from those used to evaluate speech perception in the hearing-impaired community. Some researchers have called on the APD test battery to use only non-speech stimuli in order to eliminate the influence of language on performance. However, in reality, tests of phoneme recognition (alongside word recognition) and phonetic-contrast perception are often used to evaluate hearing-impaired children (Stach, 2010). Another problem identified with behavioural testing is that it relies on the verbal responses from the client and, similar to a psychometric test, is naturally influenced by the attention, language and cognitive skills of the respondent. There is no universally accepted gold-standard set of tests. Instead, professional groups such as ASHA (2005a) advocate that audiologists use their professional knowledge and select tests (from a plethora of available ones) specific to the needs of the client. The rationale behind the variable test selection is that APD can affect children differently due to the individuality of brain organisation and the conditions that affect such organisation. An individualised approach to selection of diagnostic measures and the interpretation of results considers chronological and developmental age, language age and experience, cognitive abilities, educational experience, linguistic abilities, cultural and social background, medications, client motivation, visual acuity, and motor skills (ASHA, 2005a). Discussions about APD in associated fields of science, beyond audiology, report that analysis of APD test results requires such specialist audiological knowledge that the findings cannot be applied in any functional manner (Kamhia, 2011).

4.9 The Role of the Speech-Language Therapist in APD

According to current NZ audiological practice because APD is an auditory deficit, only an audiologist can diagnose it (Keith et al., 2019. However, SLTs are involved for assessing and diagnosing comorbid conditions (ASHA, 2005a; Keith et al., 2019). The specialist audiological knowledge required to understand and apply APD diagnostic findings to a child's everyday functioning is beyond most SLTs' foundation-knowledge base. This is unsurprising given a 2007 review of APD found that many clinical audiologists also do not have confidence in APD assessment or management techniques (Chermak et al., 2007). Bellis (2003) echoes many SLTs' concerns that the clinical utility of an APD diagnosis will remain limited until audiologists can define and explain functional management pathways (DeBonis & Moncrieff, 2008). Studies into the myriad of interventions for school-aged children with APD have found the evidence base too small and weak to provide guidance to SLTs endeavouring to choose a pathway of management (Fey et al., 2011). The tests for diagnosis of APD are variable in their application and the pathways to efficient and effective treatment options for APD are equally contentious, needing more research due to the lack of an evidence base for practical application (Kamhia, 2011). SLTs are referred children with APD for assessment and treatment. Clients, professional bodies (ASHA, AAA, and CASPA) and texts continue to suggest possible routes for assessment and treatment of APD despite the limited evidence available. One such suggestion is for phonological awareness therapy, because a failure in temporal processing and/or auditory discrimination deficits in the APD test battery may lead the audiologist to refer to a SLT requesting phonemic awareness therapy for the child. The connection between a failure on these tests and the request for phonological awareness therapy is often difficult for the SLT to understand. An SLT is unlikely to start a treatment approach without evidence of difficulties from the tests most commonly used by their profession. SLTs commonly use psychometric tests of PA, such as the comprehensive test of phonological processing (Wagner, Torgesen, Rashotte, & Pearson, 2013), which provide not only evidence of the presence of a phonological awareness difficulty, but a baseline for phonological awareness skill level. A baseline is used to form a treatment plan targeting the phonological awareness skills the child may be missing. SLTs may equally be reassured that anecdotal evidence from audiologists suggests that the recommendation for phonological awareness therapy is usually accompanied by the child experiencing or having a history of dyslexia or related literacy difficulties. SLTs are well positioned to provide phonological therapies as a treatment for APD because of their experience with other disorders of speech, language and literacy (Gillon, 2018; Snowling & Stackhouse, 2006). The arguable difference between auditory training used by audiologists and phonological awareness therapies used by SLTs has been the use of non-linguistic stimuli for auditory training (Wilson et al., 2004).The line between auditory training and phonemic/phonological awareness therapy often gets blurred in the pursuit of treatments for APD because although the linguistic basis of phonological awareness training aligns it more closely to language intervention than auditory intervention, its manipulation of sound could be considered by some to be an auditory intervention. Jack Katz is an audiologist who has developed assessments and treatments for APD using phonics-based methods such as training the child to identify and blend GPCs (Katz, 2007; 2009; Katz & Fletcher, 1998; Kaul & Lucker, 2016; Keith et al., 2019). Although often referred to in the literature, in reality Katz's commonly named Buffalo model is not widely used in audiology clinical practice. Consequently, the roles and responsibilities of the audiologists and the SLT, so neatly defined in Figure 7, can become blurred adding to the confusion around assessment and interventions for APD. However, there is clearly a role for SLT and other professionals in the assessment and provision of intervention for likely comorbid dyslexia, speech, language, and cognitive-communication disorders associated with APD (ASHA, 2005a; Keith et al., 2019).

4.10 Auditory Processing Disorder in New Zealand

The development of the *New Zealand Guidelines on Auditory Processing Disorder* (Keith et al., 2019) stemmed from a report (Esplin & Wright, 2014) on the current situation of APD in NZ. This report, commonly called the "Sapere Report," found a system that was fragmented, "difficult to access, confusing and inequitable in both access and outcome" (p. xii) for children hoping for assessment of APD in NZ. It revealed that children who were eventually able to access the specialist audiologist necessary for an assessment of APD were considered the fortunate ones, whilst many children, for reasons of funding and geography, could not access an audiologist for APD assessment. There was inequitable access to audiological services across NZ and multiple challenges being faced by families and stakeholders around obtaining a diagnosis of APD. It is hoped that with the recent release of the *New Zealand Guidelines on Auditory Processing Disorder* (Keith et al., 2019) some of these barriers to knowledge and support may be ameliorated. The document helpfully pulls together information from both NZ and international research and includes insights from American, British and Canadian guidelines to govern practice in NZ. The *New Zealand Guidelines on Auditory Processing Disorder* (Keith et al., 2019) are supported by the NZ Audiological Society and aim to not only inform but guide families and the clinical practice of audiologists and allied practitioners.

CHAPTER 5. Aims and hypotheses

The research fields of dyslexia and APDs are wide ranging and often rife with controversy and debate about possible diagnostic parameters, assessment approaches and management techniques. Conceptual models of processing help us form an understanding of the many variables involved in analysing and assisting children with these two complex disorders. The heterogeneous presentation of the populations, coupled with the dynamics involved in child development and cognition, means that linear models of processing, whilst attractive to use, are not always realistic to apply. The differing philosophical viewpoints of the professionals and researchers constructing the models influences their recommended approach to childhood APD and dyslexia.

Common to both dyslexia and APD research is the presence and importance of phonological awareness difficulties. It is widely accepted that phonological awareness plays a role in reading success. Hearing scientists are also finding that phonological awareness is connected to poor reading in children with APD. This connection is less clear and requires more research. This study aims to clarify this connection by providing the detail of phonological awareness assessment findings and reading assessment findings for school-aged children diagnosed with APD.

It is from an understanding of both hearing and reading science literature that the current study's hypotheses were formulated. The phonological awareness skills of the school-aged children diagnosed with APD were evaluated with a readily available psychometric test to establish whether in fact these children did exhibit phonological awareness difficulties. The literacy skills of the children were also assessed in order to seek a possible correlation between phonological awareness and the most common functional outcome of phonological awareness difficulties, dyslexia. It was important to use tests of phonological awareness and literacy readily available to SLTs because they are currently called upon to provide treatment for deficient phonological awareness skills. The aim was to provide information about this cohort of children which could be translated into useful clinical practice for SLTs who may find themselves in the position of bridging the gap between an APD diagnosis and functional-treatment approaches.

The motivation for this research came from the author's question about the SLT's role in two referral groups. One was the ever-increasing requirement to be involved with children diagnosed by audiologists with APD. The other was the percentage of these children who had concomitant literacy challenges, which audiologists verbally report may be due to APD. The literature produced by the supporting associations of these two professions increasingly reinforces the role that SLTs should play in both these groups. The common link seems to be the abilities of these diagnostic groups to secure the necessary phonological awareness skills to access learning. Undoubtedly SLTs have the background knowledge and training to assess and manage phonological deficits in children with speech-sound disorders. But do they for APD and dyslexia, and if so, what assessments would find phonological awareness deficits within a population of children with APD? These questions naturally lead on to the key question that will be answered in this study. What are the phonological awareness abilities of school-aged children with APD in NZ? Considering the broader implications of phonological difficulties for literacy acquisition, the current study will also ask, if phonological problems are present in the APD group, have literacy difficulties been a factor in the clients learning journey?

The current study has two hypotheses based on a critical review of the literature:

Hypotheses:

- **I. School-aged children with APD have phonological awareness difficulties**
- **II. Phonological awareness difficulties in school-aged children with APD are associated with measurable literacy difficulties including a parent report of dyslexia and/or a speech-in-noise measure.**

CHAPTER 6. Method

6.1 Background

This study is a mixed-methods design using a selection of the assessment data obtained from a wider project called Phonological Processing Treatment (PPT) for Children with Auditory Processing Disorder. The current study analysed the data from the phonological awareness, literacy and speech-in-noise tests collected from the PPT. This chapter outlines the methods used to recruit the participants, select tests and conduct assessments.

6.1.1 Phonological Processing Treatment (PPT) study.

The PPT was a mixed-methods randomised control trial study in which participants had 12 sessions of phonemic awareness therapy with an SLT. The purpose of the PPT was to provide phonological awareness therapy for school-aged children with APD and establish if the treatment improved their hearing (as measured by the speech-in-noise test). Participants of the PPT were randomly assigned to three groups 1) phonological awareness therapy, 2) phonological awareness therapy using an amplification device, and 3) delayed phonological awareness therapy using an amplification device (control group). The participants of the PPT were assessed before treatment and after treatment using a broad battery of tests and questionnaires (child, teacher and parent). The PPT was one of five research projects investigating assessment and treatment of children with APD. Oticon Foundation (Denmark) provided the funding and the research was conducted by the University of Auckland. The principal investigator was Dr Suzanne Purdy, with Dr William Keith as co-investigator. The team included Melissa Baily (audiologist) and Lucy Sparshott (SLT) as investigators and research assistants.

6.1.2 The current study.

The current study analysed a selection of assessment data collected from the first testing phase of the PPT. This study analyses the phonological awareness, literacy and speech-in-noise skills only. Table 6 provides a list of the measures used and a brief description of their purpose, which are described in greater detail under each sub-heading of this chapter.

Table 6

List of Measures Used in the Current Study

Measures	Abbreviation	Purpose
Comprehensive Test of Phonological Processing 2nd edition	CTOPP-2	A test to provide standardised measures of reading-related phonological processing
Wheldall Assessment of Reading Passages	WARP	A test to provide an accurate measure of reading fluency from norm-referenced data
South Australia Spelling Test—revised	SAST	A test to provide quick screening of single-word spelling and to provide a quantitative measure of a student’s current standing within the class and their age group

Measures	Abbreviation	Purpose
Letter-Sound Test	LeST	A test to screen for and diagnose possible gaps in GPC knowledge
BKB-SIN	BKB-SIN	A test to measure ability to understand speech in background noise
Parent/caregiver report of dyslexia	HFQ3Lit	A question used to measure parents' knowledge of the child's history of dyslexia and/or possible literacy challenges (reading and/or spelling)

6.2 Ethics Approval

Ethics approval was granted for this research project by the University of Auckland Human Participants Ethics Committee, (protocol # 019949), on 23 August 2017 (Appendix B).

6.3 Participants

The current study used data from 30 of the 32 school-aged children involved in the PPT: 20 boys and 10 girls. The children selected for this study were all aged between 7 and 10 years of age. All of the children had a recent diagnosis of APD made by an audiologist. All children and their parents completed forms consenting to participation in the study (children completed Appendix C or D, parents completed Appendix E or F). This diagnosis was deemed current and valid if it was made within the 15 months leading up to the day of assessment for this research.

All 30 participants met the criteria for a diagnosis of APD by their audiologist. The diagnosis of APD was defined as (AAA, 2010):

- a score two standard deviations or more below the mean for at least one ear on at least two different behavioural central auditory processing tests;
- or, if poor performance is observed on only one test but is accompanied by significant functional difficulty in auditory behaviours reliant on the process assessed;
- or, if poor performance is observed on only one test with a score three standard deviations or more below the mean.

The participants presented with different patterns of performance on a diverse range of behavioural APD tests. Anecdotal evidence suggests the audiologists used the most current evidence-based APD tests for their diagnostic battery and NZ norms where available (Kelly, 2007). All 30 children were recruited from the Auckland city region of NZ.

6.3.1 Inclusion/exclusion criteria.

Due to the parameters enforced by the overarching larger treatment study (PPT) participants were excluded from this study if they were undergoing any treatment for APD at the time of participation. Parent/caregivers were asked to exclude their child if they did not fall within the normal range of cognition, or if their behaviour would not allow them to participate in the 2 ½ hour test battery and subsequent one-on-one treatment programme prescribed by the principle treatment study (12 sessions). A determination of adequate cognitive skills was based on parental report and/or cognitive test information available from educational psychology or other professional reports (if available). Two of the 32 PPT participants were excluded from analysis in the current study because they fell outside the age range.

6.3.2 Sampling methodology.

Children were recruited into this study via the PPT using convenience and mixed purposeful-sampling methods. The children were recruited via a specialist APD clinic based in Auckland and via a poster advertisement (see Appendix G) and word of mouth. Snowballing then occurred as interest in the wider APD community grew, the benefit being a more representative sample of the population. The advertisement was used to promote the PPT as part of the five wider research studies into APD the University of Auckland was conducting at the time. The SoundSkills clinic also used the advertisement as an email to the parents of children diagnosed with APD in the 15-month time frame. Parent/caregivers were also informed of the research via the audiologist at their SoundSkills assessment appointments. The advertisement was posted on social media networks for SLT and audiology associations, an APD family-support group, a non-profit organisation—Specific Learning Difficulties (SPELD) NZ—and SoundSkills. Interested parents/caregivers were asked to email the researcher and were then sent a brief overview of the APD research studies which were recruiting at the time (Appendix H). The overviews outlined the purpose, time commitment and inclusion/exclusion criteria for participation for each corresponding study. The parents then self-selected the research study most suitable for them and their child. This resulted in children being recruited from audiologists in private practice, public health departments, and by being nominated for assessment for participation in the PPT. If contacted directly requesting participation in the PPT, parents/caregivers were emailed the brief overview for the PPT (Appendix I) which informed them that the phonological awareness treatment method used in the PPT was one which was useful for children with literacy problems, and that they would need to agree to attend a clinic session for two 2 ½ hour assessment appointments. The brief overview also stated that their child would receive 12 sessions of one-on-one therapy during the PPT, but could select the location and time of this: school, clinic or home. If the parent/caregiver expressed an interest in their child's participation in the PPT, they were sent an information sheet (Appendix J or K), history form (Appendix L) and asked to sign and return the consent forms (Appendix E or F). The advertisement produced expressions of interest from parents whose children had not a diagnosis of APD but whom the parents felt exhibited the characteristics of APD. If, after a discussion with the researchers, the child met the criteria for participation, except for having an APD diagnosis, then the parents were able to opt in to a diagnostic assessment with the research audiologists. They agreed to this on the understanding that if a positive diagnosis was received then they would be expected to participate in the study. These parents received a different information sheet (Appendix M) and consent form (Appendix N) to sign. Once assessment was completed, all parent/caregivers received an assessment report (Appendix O) for their child.

6.3.3 Sample representation.

The participants resided in Auckland, NZ. In Auckland, APD services are not routinely provided by private or public audiologists. The use of the advertisement was an effort to reach more of the school-aged population who may have APD in NZ.

6.3.4 Sample population.

After applying the inclusion/exclusion criteria, the sample consisted of 30 school-aged children diagnosed with APD. All had consented to participate in the PPT, as had their parent/caregivers and school teacher (in order to answer a questionnaire for the PPT). The method of advertisement and the amount of self-selection to meet the criteria for consent and participation meant that the population is unlikely to be representative of the school-aged population of children with APD in Auckland.

6.4 Assessments and Procedures

This rest of this chapter will outline the purpose, procedure and an interpretation guide of each of the selected measures used in the current study. All the measures were objective, standardised measures except the history form question. This was a mixed-methods but primarily quantitative study whose test measures were in part dictated by the requirements of the broader study (PPT). The measures selected for analysis were based on the study question: What is the relationship between literacy measures and phonological awareness abilities in school-aged NZ children diagnosed with APD?

All children had received a diagnosis of APD in the past 15 months with 70% (n=21) diagnosed by an audiologist at SoundSkills clinic, 20% (n=6) diagnosed by a research audiologist, and 10% (n=3) diagnosed by a public health audiologist. Before attending the assessment appointment, the parent had already been sent the appropriate information form (see Appendices J or K). They had also completed and returned the appropriate consent form and the history form (see Appendices E or F and L respectively). When they arrived at the assessment session, the examiner spent some time building rapport with the child and the parent. The child's assent form (Appendix C) was then explained and the child asked to complete this. The child's hearing was screened using otoscopy, tympanometry and pure-tone audiometry. All children passed the hearing screen prior to participating in the testing. All assessments were administered in one session in a sound-proof booth at either SoundSkills clinic (the 2018 cohort n=17) or the university clinic (the 2019 cohort n=13).

An attempt was made to vary the order of the tests in order to minimise the possible impact of behavioural factors on the test situation, e.g., fatigue, reduced attention, distractibility. For this reason, 17 of the children had the CTOPP-2 as their third test and the LeST as their seventh test. The remaining 13 had the LeST as their third test and the CTOPP-2 as their seventh test. The WARP offered a variety of reading passages as stimulus, therefore 18 of the children read Passage 2, and 12 children read Passage 4. All other tests did not offer an alternative stimulus, so the same test presentation took place.

The PPT assessment battery contained additional tests such as a test of narrative language (TNL-2) and questionnaires, but these have not been included in the current study. The decision to exclude these tests from analysis was made in order to focus on the aims of this study which were to establish the phonological awareness abilities of the children and an association with literacy and speech-in-noise measures (See Table 6).

6.5 Phonological Awareness Assessment

Wagner, Torgesen and Rashotte first designed the CTOPP in 1999 to provide standardised measures of reading-related phonological processing skills. The revised CTOPP-2 (2013) version used here claims to cover most relevant phonological processing features commonly needed by competent readers: phonological awareness, phonological memory and rapid-naming ability. Phonological awareness only was analysed by collating the scaled scores of the three phonological awareness subtests: Elision, Blending words and Phoneme isolation. This measure is called the phonological awareness composite score (PACS). The CTOPP-2 was conducted by the same SLT and has a total of seven subtests which can take up to 40 minutes to administer

The CTOPP-2 is normed on 1900 individuals across the USA. The authors also claim that validation studies have shown the CTOPP-2 and its subtests (and in particular the phonological awareness tests) correlate significantly with reading tests administered a year later. The CTOPP test versions were used extensively in research studies, with a database search on the term CTOPP returning over 4,000 results (PsycInfo). The CTOPP-2 is also commonly used in SLT clinical practice and is accessible to SLTs in NZ. The CTOPP-2 and earlier version CTOPP are widely used tests primarily due to their research-based test development process and a strong programme of standardisation (Hintze, Ryan, & Stoner, 2003). A review of CTOPP-2 by Tennant (2014) states the phonological awareness subtests and the PACS have adequate floors for the age range of the children in the current study. Sharma et al. (2018) also looked at the phonological awareness ability of children with APD by using the Queensland University Inventory of Literacy (QUIL) test (Dodd, Holm, Orelemans, & McCormick, 1996); however, the CTOPP-2 was chosen for the aforementioned reasons and on the recent verbal recommendation in a personal correspondence with Dr Sharma. The phonological awareness subtests and their composite score (PACS) are the focus here because phonological awareness is the processing feature influenced by the auditory neural stability (Bonacina et al., 2019) relevant to auditory processing and “reading disability” (Dickens, Meisinger, & Tarar, 2015). By 7 years of age, the CTOPP-2’s phonological awareness subtests focus on phoneme units (not larger syllable units), so, strictly speaking, this sample was tested on phonemic awareness ability. Snowling and Stackhouse note, in the second edition of their 2006 text *Dyslexia: Speech and Language Therapists*, “as reading develops, the performance of phonological awareness tasks typically improves and therefore more sensitive measures are needed for older children” (p. 71). The CTOPP-2 phonological awareness subtests have been used in studies to measure phonological awareness in children diagnosed with APD (Bonacina et al., 2019).

6.5.1 Phonological awareness coding conventions.

The CTOPP-2 is purported to index those phonological processing features germane to competent readers and provides seven subtests to measure these. The three core phonological processing skills required by competent readers are 1) phonological awareness, 2) phonological memory and 3) rapid-naming ability. Only the phonological awareness results were analysed here. The Elision, Blending words, Phoneme isolation subtest scaled scores were combined to find the PA score and compared to a norm-referenced table. The CTOPP-2 offers descriptive terms for severity of the scores (Table 7).

Table 7

Scaled and Composite Score Ranges with Description of Severity Terms (Wagner et al, 2013)

Description of severity	**Very poor**	**Poor**	**Below average**	**Average**	**Above average**	**Superior**	**Very superior**
Scaled score	1–3	4–5	6–7	8–12	13–14	15–16	17–20
Composite score	<70	70–79	80–89	90–110	111–120	121–130	>130

6.5.2 Phonological awareness subtests: Elision, Blending words and Phoneme isolation.

In the Elision subtest the participant was required to say a word after omitting a particular phoneme. The task begins with larger units of sounds (one of the words in a compound word) and requires increasing skilfulness in linguistic complexity—from words, to syllables, to onset and rime units, to individual phonemes within consonant clusters e.g. Say “winter”. Now say “winter” without saying /w/.

In the Blending words subtest, the participant was required to blend given linguistic units of increasing complexity to make up new words e.g. What word do these sounds make? j-u-m-p (jump).

In the Phoneme isolation subtest, the participant was required to identify an individual phoneme (e.g., first, last, middle) in a given word e.g. What is the *first* sound in the word *fan*?.

6.6 Literacy Assessments

Literacy abilities were measured by assessing reading fluency, single-word spelling and GPC knowledge.

6.6.1 Reading fluency.

The Wheldall Assessment of Reading Passages (WARP; Madelaine & Wheldall, 2013) an Australian designed and normed standardised measure of reading fluency, was chosen because it is claimed to correlate highly with other measures of both reading accuracy and reading comprehension and has been used in related studies of APD when measuring reading fluency (Sharma et al., 2006; Sharma et al., 2018). WARP claims to be a curriculum-based measure which provides an accurate measure of reading fluency from norm-referenced data, so it was a useful parallel test to the summative and curriculum-based measures favoured within the NZ teaching context. Teachers in NZ tend to conduct summative and/or curriculum-based measures as a measure of reading progress in preference to standardised tests (Cameron, Carroll, Taumoepeau, & Schaughency, 2019). In addition to being a practical curriculum-based measure, the WARP results were able to be adapted to provide an age-equivalent result important for the research aims of this study. The Burt word-recognition reading test, a NZ test, was not selected because there was some concern expressed anecdotally by teachers that the word list is too dated (1974) and therefore the test itself lacks relevancy as a curriculum-based measure.

The WARP has a short administration time and although the designers recommend conducting one of the three initial assessment passages for one-off testing, only one of the 10 “progress” passages was used here. Passages were chosen as suitable for use with NZ children if the vocabulary would be familiar, e.g., contained fewer Australian colloquial words (e.g., “darls”). Progress-reading Passage 2 was administered to 18 of the sample and Passage 4 to 12 of the sample.

The child is asked to read aloud in 1 minute as many words in the 200-word passage as they can. The number of words read accurately is taken as the score. Children were asked to read the passages as quickly and accurately as possible within a minute. The large test battery for the PPT meant that time constraints dictated that only one passage was chosen for this reading task. The manual suggests that the average of three passages may provide a more accurate indicator of words correct per minute (wcpm). The wcpm is used to find an age equivalency on the test’s normative data. This test was normed initially on 1,000 students in Year 2 to Year 5 and then on a second study of 261 students to obtain grade-based norms. The WARP designers (Madelaine & Wheldall, 2002) readily admit the average/mean WARP scores are “extrapolated approximations” (p. 12) of the benchmark (“norm”) to guide reading instruction, and are not based on large representative or random samples such as true norms in a standardised test would be. To alert the tester to the children who fall in the very lowest reading-fluency ability, the WARP provides a table with the bottom quartile (25%) cut-off scores for each year group.

6.6.1.1 Reading fluency coding conventions.

The WARP is a curriculum-based measure which provides a lower and higher average range of wcpm for Australian students in Years 2 to 5. Being set in NZ, it was necessary for this study to adapt the WARP for use with the NZ population because Australian (New South Wales) school years 2 to 5 do not equate to NZ school years 2 to 5. Therefore, Australian years 2 to 5 were translated to an average age for that year e.g., In NSW, a Year 2 average age would be approximately 7½ years old. For each participant, the age closest to theirs at the time of testing was used to compare against the range of wcpm. If the participant’s wcpm fell below the range (e.g., age 7½ is 57 to 82 wcpm) then the description of severity code was below average for reading fluency. If they scored above 82 wcpm, they were described as above average in their performance reading passages. Children were allocated to below average, average or above average depending on whether their score fell within the 50% range limits (wcpm) for their grade age (Madelaine & Wheldall, 2002, Table 2, p. 12). For the purposes of this research, the NZ children did not match the Australian grade, so their grade age was taken as the mean age. This became Grade 2 = 7yr 6m, Grade 3 = 8yr 6mth, Grade 4 = 9yr 6mth, Grade 5 = 10yr 6m, based on the mean age of months provided. The closest age to the child’s actual age was used as a benchmark for working out whether they were below (coded as 1), average (coded as 2) or above average (coded as 3).

6.6.2 Spelling of single words.

Westwood’s (2005) South Australian Spelling Test (SAST) was used to assess the single-word spelling ability of the children. The SAST is a standardised test for the age range 6 years to 16 years

(Westwood, 2008). The main purpose of this 70-word test is to provide a quick screening instrument of single-word spelling and to provide a quantitative measure of a student's current standing within the class and their age group. The SAST Form A used here is a modified version of the graded word list (1970) compiled in Britain by Dr Margaret Peters of Cambridge University. Originally standardised on children in England, Form A was later (1978) normed on a large representative sample of South Australian children. These Australian norms were checked and updated in 1993, and again in 2004, on 10,692 South Australian children. Most of the 70 words used were derived from Schonell's (1950) earlier standardised spelling tests S1 and S2. The original Schonell spelling lists were formulated from high-frequency words (used by children in reading and spelling); tests derived from these are similarly formulated. The SAST moves through easier- to harder-to-spell words, of which there are 70 in total. The SAST has a Form B available which is interchangeable with Form A.

During the test, the SLT clearly said the word aloud, and then embedded the word in a sentence and then repeated the word. The participants recorded their written responses on a numbered sheet. Testing was discontinued after a student failed a block of 10 consecutive items (ceiling). Only the correct responses to the ceiling were scored. When marking, participants were not penalised for reversals of *b* and *d* as per SAST instructions.

6.6.2.1 Spelling coding conventions.

The spelling test used here was the Australian designed SAST, so again it was adapted for use to suit the NZ sample. Raw scores (total of items correctly spelt) were evaluated against the range of scores typical for students of their particular age level (as per the instructions provided by the SAST). This raw score was then converted into an approximate spelling age for that student (see SAST Instructions, Table 2, for Form A) and used to determine where the participant fell within the range of scores for his or her age level. An average score (coded as 2) indicated a score within the spread of scores which 50% of the students of that age achieve. Above average (coded as 3) was a score above that which 50% of the age group would score. Below average is a score in the range of the lowest 25% of spelling scores for that age (coded as a 1). A critically low score (coded as 0) represents the score below which only 10% of the age group would be scoring.

6.6.3 GPC knowledge.

The LeST, an Australian test authored by Linda Larsen, Saskia Kohnen, Lyndsey Nickels and Genevieve McArthur (2015) was used. The LeST claims to be both a screening and diagnostic tool to test GPC and is available online at no charge. The authors claim the LeST tests GPCs more specifically than non-words (commonly used by other tests), and recommend absent GPCs can be a target for reading intervention. Larsen et al. (2015) explain that the GPCs were selected on frequency of occurrence and cross-referenced with the word vocabulary of children. The stimuli are presented with the most commonly occurring first. Larsen et al. (2015) found the LeST to have high test–retest and inter-rater reliability and appropriate criterion validity.

The LeST Stimulus form shows the individual 51 graphemes and multi-letter GPCs and asks the child to say the associated phoneme. There is no ceiling or discontinuation rule for the LeST. Tables of reference are provided to calculate the child's z-score, percentile rank and descriptive classification. The number of corrected items is counted to obtain the total number of correct items (/51), the raw score. The appropriate comparative Australian grade for the participant is decided by referring to the norms table provided (i.e., Kindergarten, Grade 1, Grade 2, or Grade 3).

6.6.3.1 GPC coding conventions.

The LeST scoring was adapted for the purposes of this NZ-based study by using the age ranges listed next to the Australian-based grades to calculate the percentile and z-scores of the children in the sample. The LeST z-score is a standard score with a mean of 0 and a standard deviation of 1. A z-score of 0 means average performance but the LeST derives description of severity ratings from the ranges which the z-scores may fall in: below -2 is well-below average, -2 to -1 is below average, -1 to +1 is average, +1 to +2 is above average, +2 is well-above average.

6.6.4 Parent/caregiver report of dyslexia.

Parents/caregivers were asked about their child's history of possible literacy difficulties in the history form (see Appendix L). The purpose was to gather data about the child's history of dyslexia and or other literacy challenges. To rule out possible confusion around terminology and diagnostic parameters of dyslexia, a broadly descriptive question form was purposefully used. This was in an effort to gather any possible history of reading and/or spelling challenges. Parents/caregivers were asked to choose "yes/no/not sure" as a response to: "Has your child experienced any of the following: Diagnosis/difficulty with literacy/reading/spelling (or dyslexia)." The history form was sent with the consent form to the parent/caregiver to be completed prior to assessment.

6.6.4.1 Parent/caregiver report of dyslexia coding conventions.

The parents/caregivers ticked a box for yes, no or not sure. These were then collated and coded for use in this study.

6.7 Speech-in-Noise Test

The BKB-SIN speech-perception test designed in the USA by Etymotic Research Inc. (2005) was originally to measure adults' ability to understand speech in background noise—one of the biggest problems reported by adult hearing-aid users. It has since been used for children with hearing impairment and most recently for children with APD. The BKB-SIN claims to measure the child's ability to hear short sentences when there is competing background noise. Consequently, the noise in the background gets louder and the child needs to listen harder to hear. It was included in the PPT to measure improvement in listening after treatment.

The BKB-SIN uses recorded sentences from the Bench-Kowal-Bamford Sentence test (Bench & Bamford, 1979) spoken by a male talker with an American accent, and was designed to test the listener's ability to hear in background noise. Originally, this popular open-set speech-perception test was developed for use with hearing-impaired children (usually >8 years of age) but the designers suggest it can be used to screen children suspected of having APD. The BKB-SIN was administered in quiet conditions (a sound-proof room) but can be administered in the presence of background noise. The recording was kept in an audio file on a laptop computer and transmitted through TDH headphones binaurally through an audiometer to the child sitting in a sound-proof room. Eight lists of 10 sentences are recommended as suitable for use with clients with normal hearing (BKB-SIN manual), and, from these, three list pairs were chosen as suitable for use with children in NZ and in the PPT (Lists 2, 6, and 8). Some of the other sentence lists were excluded due to featuring some American words/language not typically used in NZ. The test was conducted at 40dBHL following recommendations from a pilot study conducted by a research audiologist for another project. This is despite the published norms being 70dBHL and a recommendation for testing children with APD at 50–70dBHL (BKB-SIN manual). The constant background four talkers babble increases in volume at each sentence. The number of correct key words repeated by the participant for each list is scored.

6.7.1 Speech-in-noise coding conventions

Speech-recognition thresholds in noise, defined as the signal-to-noise ratio (SNR) that produces 50% correct whole-sentence recognition were calculated (BKBSNRCode) for this study.

The average SNR ranges for children aged 7 to 10 years of age are available in the BKB-SIN manual and were used to indicate a possible severity of difficulty. An SNR score calculated at or above 3.3 is significant difficulty hearing in noise, 2.1 to 3.2 is more difficulty hearing in noise, and -0.4 to 2.0 is normal ability to hear in noise.

6.8 Auditory Processing Disorder Tests

In line with current APD assessment methods utilised by audiologists in NZ, the participants underwent a variety of behavioural tests prior to participation (Appendix D). Anecdotal evidence suggests that audiologists select from the most current evidence-based APD tests and can vary between clients. The tests were recorded from the audiologist’s APD diagnostic reports provided by the parents/caregivers, or research audiologist. Table 8 shows a list of APD tests, some of which were selected by audiologists when assessing the children.

Table 8

A List of the APD Tests Conducted on the Participants

APD subtest abbreviation	APD test name
RanDD(l) (r)	randomised dichotic digit: left ear (l) right ear (r)
DW	dichotic words
FPT (l) (r)	frequency pattern test: left ear (l) right ear (r)
RGDT	random gap-detection test
DS	*digit span
LISN-S	Listening in Spatialised Noise—Sentences
NU-6 1KHz LPFW	NU-6 1 kHz low-pass filtered words
SCAN3C_CS	SCAN-C or SCAN-3 competing sentences
DD	dichotic digits
CRW	compressed reverberated words
MLR	monaural low redundancy
MLD	masking level difference
SCAN-3:TCS	SCAN-3: Time Compressed Sentences
SCAN-3:FW	SCAN-3: Filtered Words
SCAN-3:AFG	SCAN-3: Auditory Figure Ground
SCAN-3:CS	SCAN-3: Competing Sentences

Note: This list was compiled from a second source (the child's audiology reports); *used here by the audiologist's to measure 'auditory memory'.

All children participated in screening tests for ear health and hearing. Otoscopy was used to visualise the ear drum and check for any ear canal or ear drum anomalies or presence of occlusive wax that might exclude further assessment or participation. All children were noted to have normal ear canals and ear drums bilaterally. All children underwent tympanometry via a Tympstar (Grason-Stadler, 2009) or a Titan tympanometer (Interacoustics, 2019). Type A tympanograms were recorded bilaterally for all children, consistent with normal middle-ear pressure and compliance. All children underwent a screening audiogram via a Grason-Stadler (GSI)-61 audiometer (Grason-Stadler, 2009). All children passed the audiometric screening, which required two reliable responses at 20 dB HL or softer (less intense), using the Hughson & Westlake modified technique (see ASHA, 2005b) for the following speech-dominant frequencies: 500Hz, 1000Hz, 2000Hz and 4000Hz at 20dBHL. All assessments were administered during one session in an industry-standard sound booth, meeting recommended standards (International Organisation for Standardisation [ISO], 2009) at either a private APD clinic (the 2018 cohort n=17) or the University of Auckland's Tāmaki clinic (the 2019 cohort n=13).

CHAPTER 7. Results

7.1 Introduction

The first chapters of this thesis investigated the role that phonological awareness and auditory processing plays in dyslexia, information which is a foundation for the methodology and results chapters. Both quantitative and qualitative data were collected. This is reflected in the presentation of the results which begins with a description of the sample and a regression analysis reporting the statistically significant relationship between phonological awareness difficulties (the dependent variable) and the independent variables of spelling, reading fluency, letter-sound knowledge, speech-in-noise and the parent/caregiver report of dyslexia. Descriptive statistics are then used to present the individual results of all the assessments. The results are presented to test the hypotheses that school-aged children with APD have phonological awareness difficulties and that phonological awareness difficulties are associated with measurable literacy difficulties, including a parent report of dyslexia and/or a speech-in-noise measure.

Results were analysed using SPSS (version 25) and are presented in relation to the study's overall aims. Table 9 provides the abbreviations and acronyms of the variables, and Table 10 the symbols and abbreviations of statistical analyses in this chapter. The Discussion chapter which follows will explore whether any of these literacy measures might be valuable to a practising SLT to provide assessment, support, advocacy and management direction for school-aged children with APD.

Table 9

Abbreviations and Acronyms of the Variables Used in Results Tables

Abbreviation/acronym	Descriptive phrase	Test origin
BKBSINcode	BKB-SIN Speech-In-Noise test code	BKB-SIN
BKBSNR	BKB-SIN Signal-to-Noise Ratio	BKB-SIN
HFQ3Lit	Parent/caregiver report of dyslexia	History Form Question 3
LeSTz	Letter-Sound knowledge Test z-score	The Letter-Sound Test
PACS	Phonological Awareness Composite Score	Comprehensive Test of Phonological Processing 2nd edition
SASTCode	The code used for analysis of results for spelling of single words	South Australia Spelling Test—revised
WARPcode	The code used for analysis of results for reading fluency	Wheldall Assessment of Reading Passages

Table 10

Symbols and Abbreviations of Statistical Analyses Used in Results Tables

Symbol/abbreviation	Word or phrase
Adj R^2	Adjusted R-squared
B	Unstandardised multiple regression coefficient
β	Standardised multiple regression coefficient
B	Regression coefficient
F	Observed F value
M	Mean
N	Number of observations or size of overall data set
n	Number of observations per group or size of a cell or group
p	Significance level (one-tailed test of significance)
R	Multiple *R*
R^2	Coefficient of determination or effect size
r	Zero-order correlation or Pearson's correlation coefficient
SD	Standard deviation
t	Observed *t* value
VIF	Variance inflation factor

7.2 Characteristics of the Sample

A total of 30 school-aged children with a recent APD diagnosis were sampled (N=30), with females representing a smaller proportion of the sample (37%, *n*=11) than males (63%, *n*=19). The children were aged between 7 years 6 months and 10 years 1 month. The mean age was 8.08. The frequency of age has been illustrated in Figure 10.

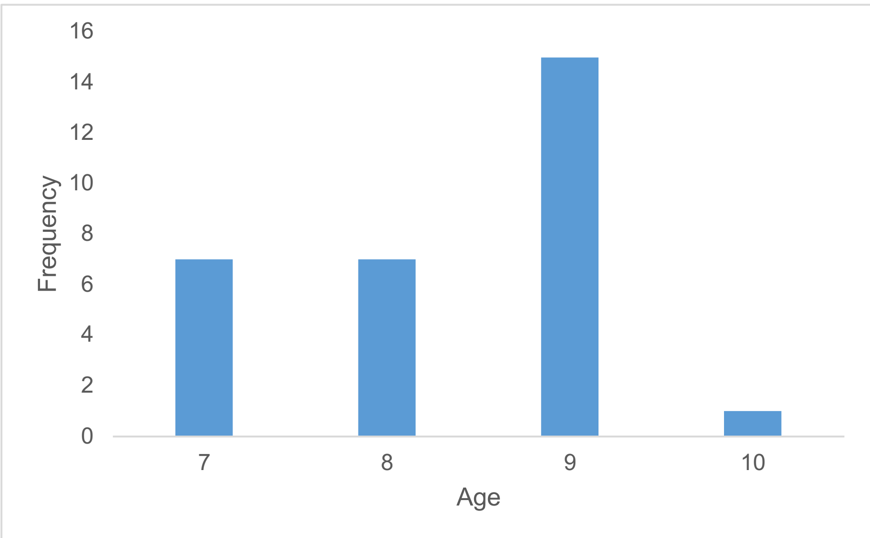

Figure 10. Frequency of children's ages.

All children passed a screening test of ear health and hearing. Otoscopy was used to visualise the eardrum and check for the presence of any occlusive wax. All children recorded Type A tympanograms consistent with normal middle-ear function on either a Tympstar or Titan Tympanometer. All children passed a screening audiogram by recording two normal responses to 500Hz, 1000Hz, 2000Hz and 4000Hz at 20dBHL.

7.2.1 Ethnicity.

Apart from one non-response, 96% of the sample identified as NZ European/Pākehā (n=29), including seven children whose parent/caregiver reported dual ethnicity, three as Samoan, one each as Tongan, South African, Chinese and Argentinian. One child identified with three ethnicities: NZ European/Pākehā, Samoan and Danish.

7.3 Literacy and Speech-In-Noise Measures as Predictors of Phonological Awareness Ability

Table 11 summarises a regression analysis which revealed that reading fluency, single-word spelling, GPC knowledge and the parent/caregiver report of dyslexia significantly predicted phonological awareness $F(8) = 3.197$, $p<.016$. $R^2 = .549$, adjusted R^2 was .377. A linear regression analysis model between the dependent variable (phonological awareness composite score) and the independent variables (reading fluency, single-word spelling, GPC knowledge and the parent/caregiver responses from the history form regarding dyslexia) were used to determine which literacy measures could predict this relationship. Assumptions were tested by examining normal probability plots of residuals and scatter diagrams of residuals versus predicted residuals. No violations of the assumptions of normality, linearity or residuals were detected. In addition, box plots revealed no evidence of outliers.

Table 11

Linear Regression of Literacy Variables Predicting Phonological Awareness Composite Score (PACS)

Predictor Variables	*r*	*B*	*β*	*t*	*p*
Age	-.125	-.937	-.079	-.493	.256
Gender	-.210	-3.935	-.187	-1.094	.133
BKBSNR	-.189	.170	.035	.123	.159
BKBSINcode	.123	.973	.074	.258	.259
SASTcode	.487	.629	.050	.210	**.003***
WARPcode	.497	6.685	.455	2.280	**.003***
LeSTz	.429	1.571	.105	.536	**.009***
HFQ3Lit	.516	6.504	.392	2.391	**.002***

Note. * = significant; BKBSNR = Speech-in-noise test signal-to-noise ratio; BKBSINcode = Speech-in-noise test signal-to-noise ratio code; SASTcode = South Australia Spelling Test code; WARPcode = Wheldall Assessment of Reading Passages test code; LeSTz = Letter-sound test z score ; HFQ3Lit = History Form Question 3, history of reported dyslexia.

Sample number = 30; F (8) = 3.197; Probability >F = .016; R-squared = 0.549; Adjusted R-squared = 0.377

The model showed there were statistically significant correlations between the dependent variable (PACS) and the literacy variables of reading fluency (r = .497, *p* = .003), spelling (r = .487, *p* = .003), letter-sound knowledge (r = .429, *p* = .009) and history of reported dyslexia (r=.516, p = 002). In terms of individual relationships with the independent variable, Table 12 shows the correlation with reading fluency and parent/caregiver report of dyslexia was of moderate strength. The correlation with phonological awareness for spelling and letter-sound knowledge was weak to moderate. Phonological awareness did not correlate with the speech-in-noise measure. This demonstrates a level of internal consistency between the measures that were chosen to assess phonological awareness and reading passages, spelling regular words, and knowledge of GPC.

Table 12

P-values between Phonological Awareness Composite Score (PACS) and the Predictor Variables that have Significant Correlations

	PACS	Age	Gender	BKBSNR	BKBSINcode	SASTcode	WARPcode	LeSTz	HFQ3Lit
PACS	---								
Age	.256	---							
Gender	.133	.167	---						
BKBSNR	.159	.245	.042*	---					
BKBSINcode	.259	.061	.173	.000	---				
SASTcode	.003**	.365	.304	.294	.287	---			
WARPcode	.003**	.294	.110	.322	.256	.000	---		
LeSTz	.009**	.373	305	.225	.387	.000	.030*	---	
HFQ3Lit	.002**	.166	.073	.240	.500	.097	.402	.062	---

Note. Significant correlations *$p<.05$, ** $p<.01$; BKBSNR = Speech-in-noise test signal-to-noise ratio; BKBSINcode = Speech-in-noise test signal-to-noise ratio code; SASTcode = South Australia Spelling Test code; WARPcode = Wheldall Assessment of Reading Passages test code; LeSTz = Letter-sound test z score ; HFQ3Lit = History Form Question 3, history of reported dyslexia.

7.4 Phonological Awareness Difficulties

The CTOPP-2 PACS and the scaled scores of the three phonological awareness subtests of Elision, Blending words, and Phoneme isolation are presented here. The descriptions of severity outlined in Table 7above, will be presented along with the descriptive statistics for the total sample (N=30). Table 13 shows the mean PACS score of 84.17. This is below average.

Table 13

Descriptive Statistics of all Variables: Phonological Awareness, Literacy and Speech-in-Noise Measures (N=30)

Code abbreviation	Mean	Standard Deviation
PACS	84.17	10.323
Age	8.73	.87445
BKBSINcode	1.00	.788
BKBSNR	3.017	2.1515
WARPcode	1.70	.702
SASTcode	1.53	.819
LeSTz	-1.1753	.69018
HFQ3Lit	1.40	.621

The bar graph in Figure 11 shows the PACS percentile rankings for all 30 children, with a trend for distribution across the lower percentile ranks (range is 1 to 63) and a mean percentile of 18. There are a few outliers, but Figure 11 illustrates that the majority of the children were distributed below the 40th percentile. This trend is reflected in Figure 12 which shows the frequency within each description of severity category for PACS. None of the children were above average, superior or very superior. Nine of the participants (30%) scored average; 10 scored below average (33%), six scored in the poor range (20%), and two scored in the very poor range (7%).

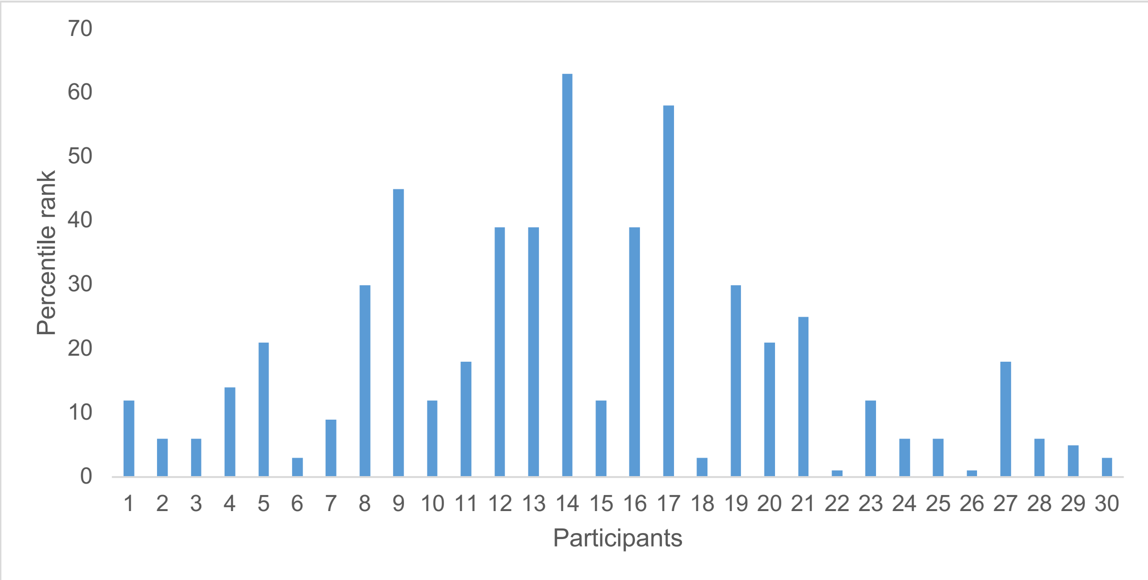

Figure 11. Bar graph showing distribution of individual PACS percentile rankings as measured by the CTOPP-2.

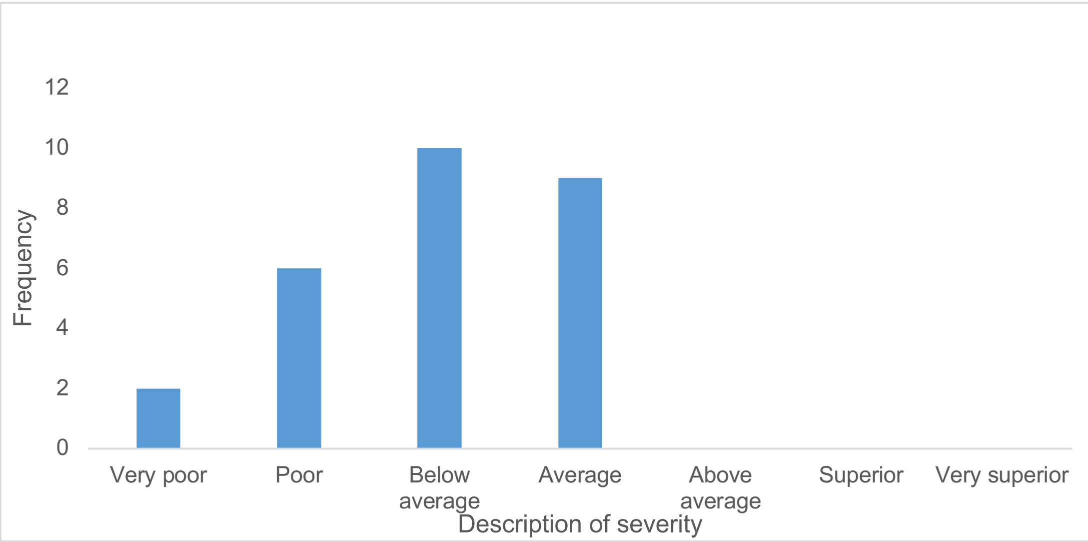

Figure 12. Bar graph showing the frequency of occurrence for PACS within the description of severity categories.

7.4.1 Elision.

Figure 13 illustrates the number of participants who scored each scaled score of the CTOPP-2 Elision subtest. The mean scaled score for the Elision subtest was 8. The normal curve has been added to represent an expected distribution of normative data as collected by the CTOPP-2 (on a sample of 1,900 individuals). In terms of description of severity (Table 7), none of the participants fell in the superior range for the Elision subtest scaled score: one scored above average (3%); 17 scored in the average range (53%) with this skewed slightly to the lower range of average; eight scored in the below-average range (26.7%); and four scored in the poor range (13%).

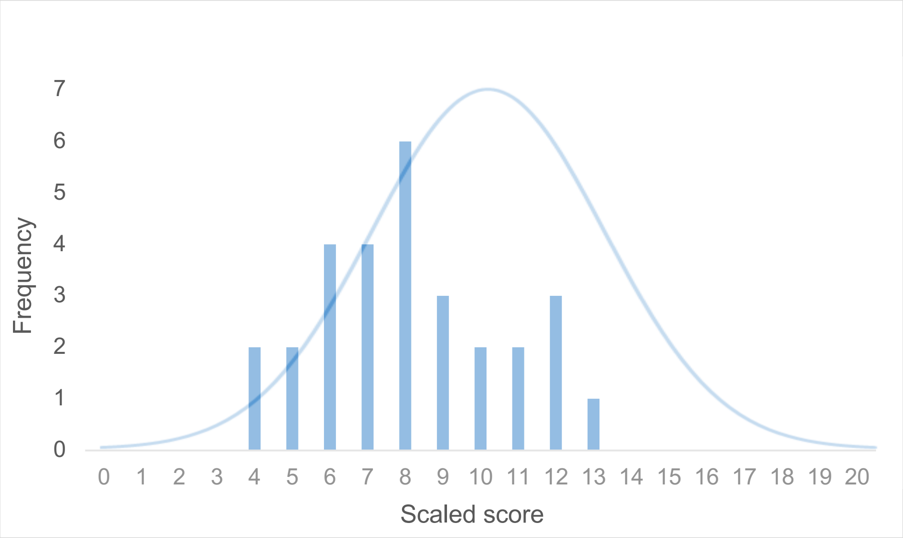

Figure 13. Bar graph illustrating frequency of scaled scores on Elision subtest (CTOPP-2).

7.4.2 Blending words.

Figure 14 indicates the number of participants who scored each scaled score of the CTOPP-2 Blending words subtest. The mean scaled score for this subtest was 6.7. The normal curve has been added to represent an expected distribution of normative data as collected by the CTOPP-2 (on a sample of 1,900 individuals). When using the CTOPP-2 description of severity to analyse (Table 7) it can be seen that none of the participants fell in the superior or above-average range, 11 scored in the average range (36%) with this skewed to the lower range of scaled scores of 8 and 9. A further 11 scored in the below-average range (36%), six in the poor range (20%) and two in the very poor range (6%).

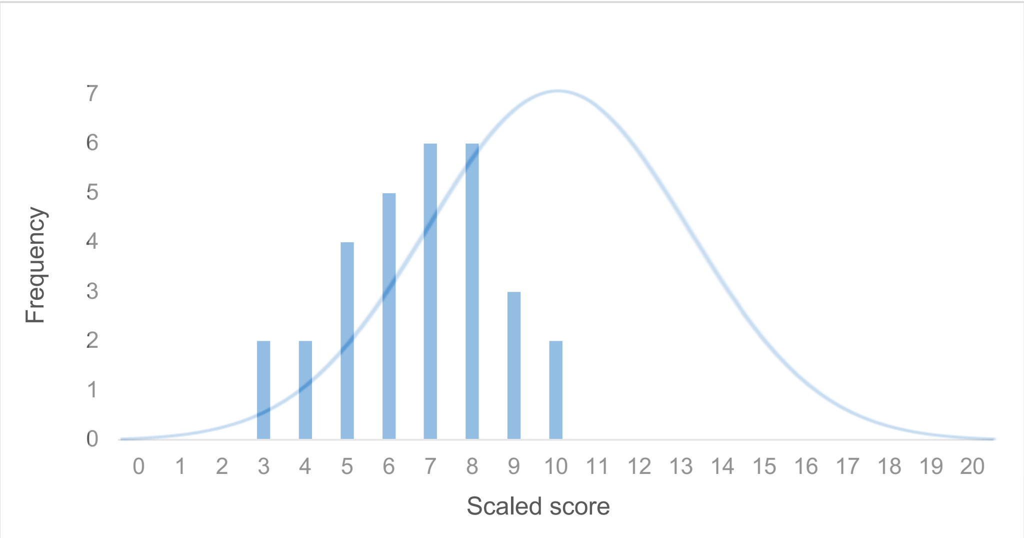

Figure 14. Bar graph illustrating frequency of scaled scores on Blending words subtest (CTOPP-2).

7.4.3 Phoneme isolation.

Figure 15 indicates the number of participants who scored each scaled score of the CTOPP-2 Phoneme isolation subtest (CTOPP-2). The mean scaled score for this subtest was 7. The normal curve has been added to represent an expected distribution of normative data as collected by the CTOPP-2 (on a sample of 1,900 individuals). Description of severity (Table 7) analysis shows that none of the participants fell in the superior or above-average range, 14 scored in the average range (47%), 10 scored in the below-average range (33%), eight in the poor range (27%) and one in the very poor range (3%).

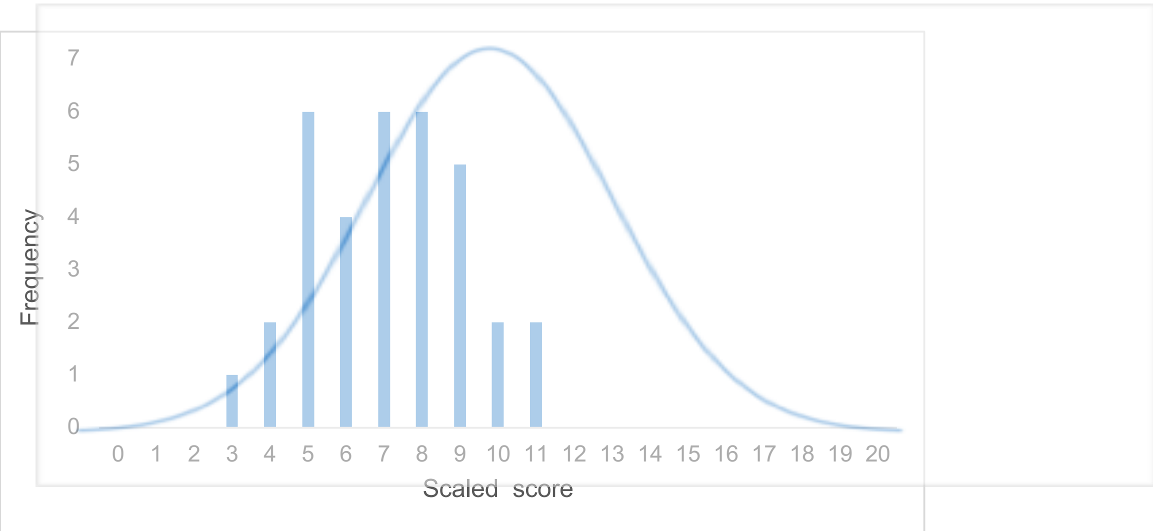

Figure 15. Bar graph illustrating frequency of scaled scores on Phoneme isolation subtest (CTOPP-2).

7.5 Phonological Processing

This study focused on the phonological awareness results and analysis from the CTOPP-2. However, for the purposes of clarification, Figure 16 indicates the sample's subtest scaled-score ranges across all of the phonological processing subtests.

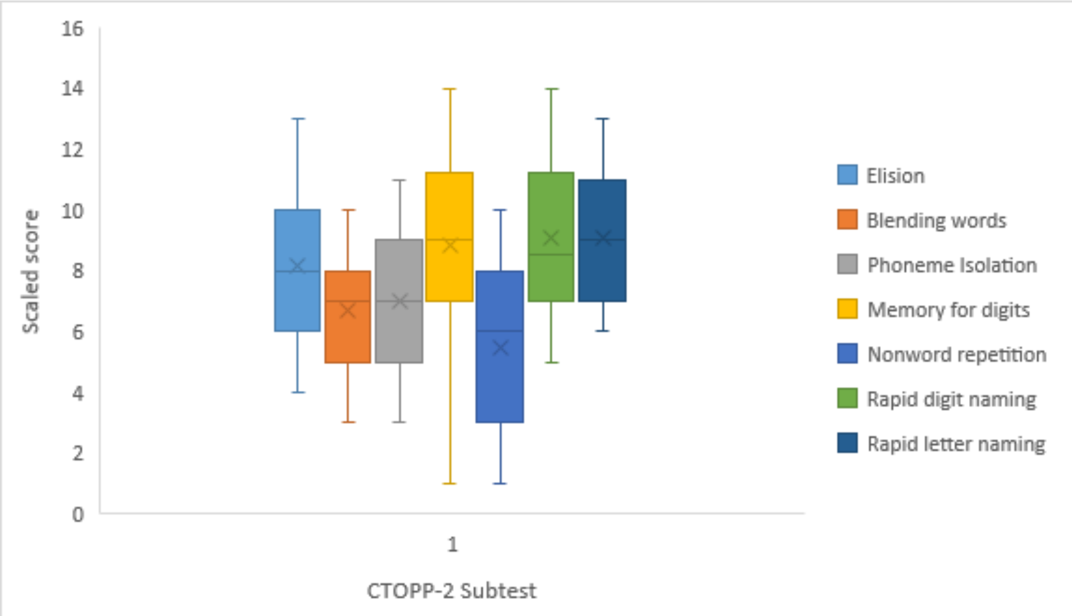

Figure 16. Phonological processing subtest scaled-score ranges (CTOPP-2).

7.6 Literacy Abilities

Adaptive coding was used to translate raw scores for the NZ sample and the SPSS analysis. Table 13 presents the mean ratings of the literacy measures for the sample. What follows is the sample results in terms of frequency of occurrence with reference to the description of severity.

7.6.1 Reading fluency.

The WARP measures a child's ability to read fluently by recording the number of correct words they read from an unknown passage in one minute, the scores are then coded into below average (1), average (2) and above average (3), as explained in Chapter 6. Table 13 presents the mean rating for reading fluency (WARPCode) as being 1.70 with a tendency for this sample's scores to be skewed to below average. Figure 17 further illustrates this tendency, with 14 participants coded as below average (47%), 13 average (43%) and three (10%) above average.

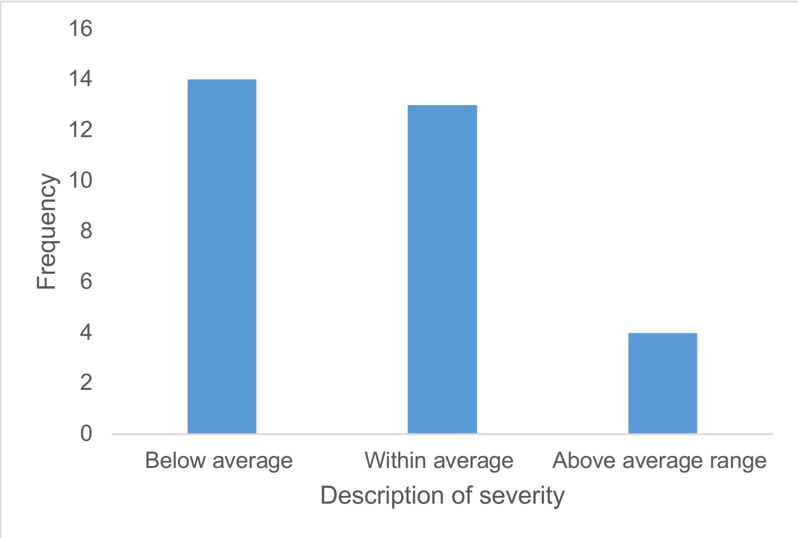

Figure 17. Bar graph illustrating the frequency of occurrence within each description of severity category for reading fluency.

7.6.2 Spelling of single words.

Spelling of single words was measured using the South Australia Spelling Test (SAST) and Table 13 presents the mean rating for the spelling measure (SASTCode) for the sample as 1.53 with a tendency for the sample to be lower than average overall. Figure 18 indicates the frequency which the sample scored in each description of severity category. Four were in the critically low range (13%), 14 below average (47%), 16 were average (53%) and one child was above average for spelling single words.

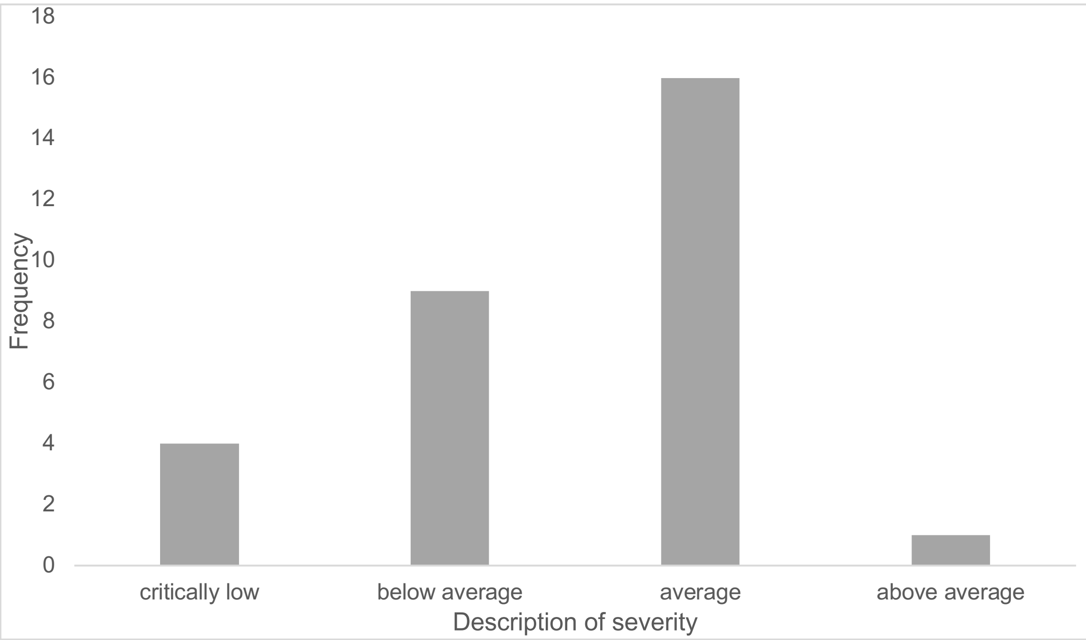

Figure 18. Bar graph illustrating the frequency of occurrence within each description of severity category for single-word spelling.

7.6.3 GPC knowledge.

Knowledge of the GPC was measured using the Letter-Sound Test and Table 13 presents the mean rating for the sample in the below-average range of -1.1753. The z-scores of the sample ranged from -0.15 (1st percentile) to -2.34 (44th percentile) with a mean z-score of -1.1753. All participants were in the bottom 50th percentile range. Figure 19 indicates the distribution of the z-score test results with reference to the description of severity and shows that five children were well-below average (17%), 11 were below average (36%) and 14 were average (47%).

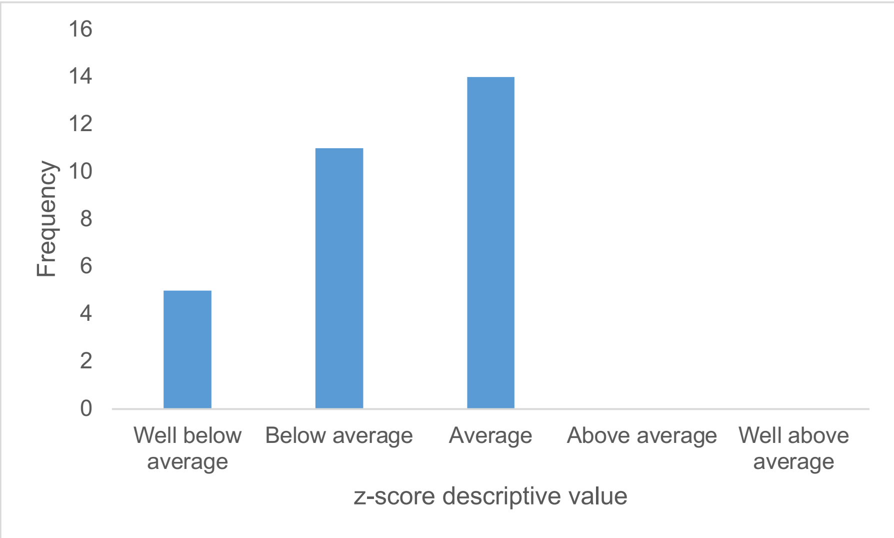

Figure 19. Bar graph illustrating the frequency of occurrence within each description of severity category for GPC.

7.6.4 Parent/caregiver report of dyslexia

Figure 20 shows the parent/caregiver response to whether their child experienced diagnosis/difficulty with literacy/reading/spelling (or dyslexia) with 66% (n=20) replying “yes.” Over a quarter of the parents (26.7%; n=8) responded “not sure” to the same question and 6.7% (n=2) responded “no.”

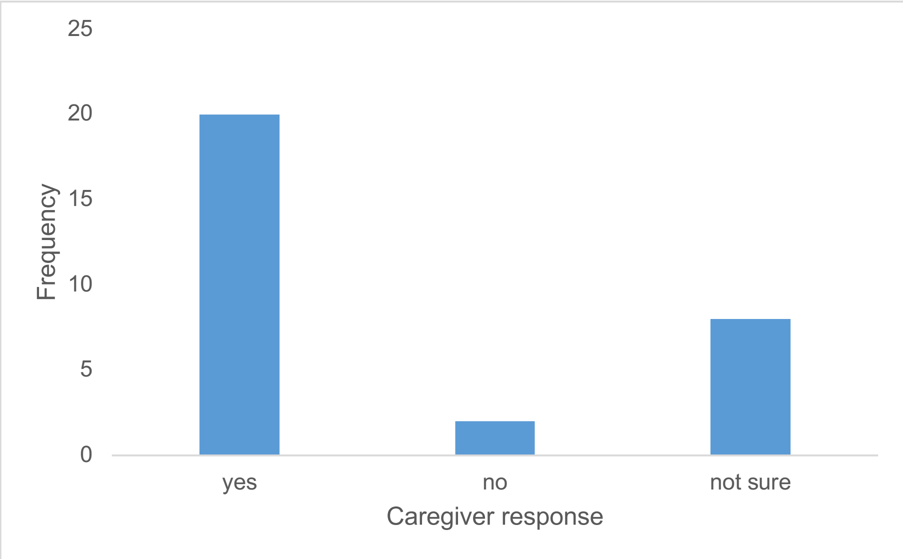

Figure 20. Bar graph showing parent/caregiver report of dyslexia.

7.7 Speech-in-Noise Ability

Figure 21 illustrates that 30% of the participants experienced significant difficulty hearing speech in noise as measured by the BKB-SIN (*n*=9), 40% (*n*=12) had more difficulty (than average) hearing in noise and 30% had average ability to hear in noise (*n*=9).

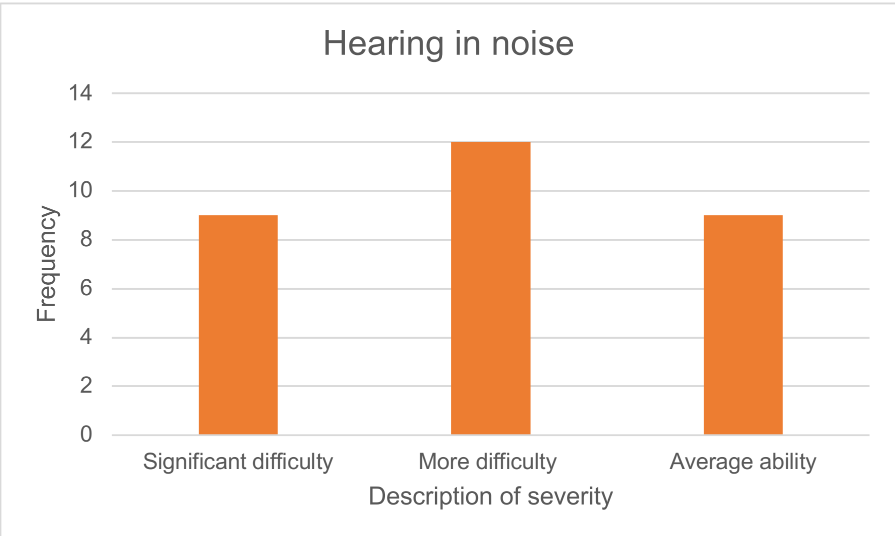

Figure 21. Bar graph illustrating the frequency of occurrence within each description of severity category for ability to hear speech in noise (BKB-SIN).

7.8 Auditory Processing Disorder Test Results

Table 14 shows the variety of APD tests named for use to diagnose APD in this sample. Data were gathered from the diagnostic APD reports provided by the parent/caregivers. The table also shows the percentage of participants tested by each of the tests. The percentage that passed or failed is illustrated in Figure 22.

Table 14

APD Tests Used to Assess the Sample. Tests are Grouped by Purpose Based on the Format Followed by New Zealand Guidelines on Auditory Processing Disorder (Keith et al., 2019) and the ASHA (2005a) Definitions for Auditory Processes (pp.3, 14–15)

Test purpose	Test name	Number of participants tested using this test	Number of participants (tested with this test) who passed this test*	Number of participants (tested with this test) who failed this test*
Dichotic listening	DDT	46.6%; n=14	42.8%; n=6	57%; n=8
	RDDT Right ear	56%; n=17	58.8%; n=10	41%; n=7
	RDDT Left ear	56.6%; n=17	70.6%; n=12	29%; n=5
	DWT	90%; n= 27	14.8%; n=4	85%; n=23
	SCAN-3: Competing Sentences Test	36.6%; n=11	36.4%; n=4	63.6%; n=7
Distorted speech	SCAN-3: Filtered Words Test	6.6%; n=2	100%; n=2	0%; n=0
	SCAN-3: Time compressed sentence test	10%; n=3	(1 was recorded as a "borderline" pass)	66.6%; n=2
	\NU-6 1KHz LPFW	70%; n=21	42.9%; n=9 (1 was recorded as a "borderline" pass)	39.7%; n=12
Spatial segregation	LiSN-S	86.7%; n=26	34.6%; n=9	65.4%; n=17
Temporal processing	RGDT	86.7%; n=26	50%; n=13	50%; n=13
	FPT	93%; n=28	32%; n=9	67.8%; n=19 (failed in one or both ears)
Speech understanding in background noise	SCAN-3: Auditory Figure Ground at 0dB	16.7%; n=5	40%; n=2	60%; n=3
	SCAN-3: Auditory Figure Ground at 8dB	6.7%; n=2	0%; n=0	100%; n=2

*failed in one or both ears

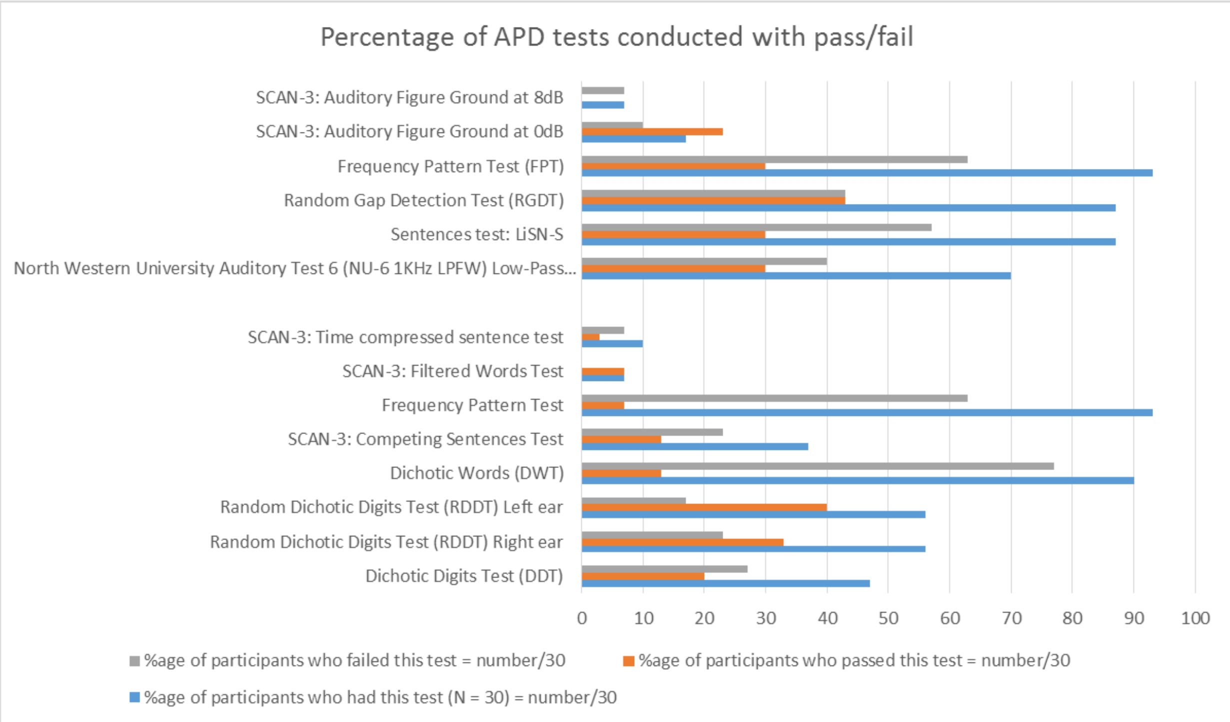

Figure 22. Percentage of participants who passed/failed APD tests.

CHAPTER 8. Discussion

This was a mixed-methods study design to show whether 30 school-aged children diagnosed with APD had phonological awareness difficulties. In addition, analysis was conducted to indicate if phonological awareness difficulties were associated with measures of literacy (reading fluency, single-word spelling and GPC knowledge) and speech-in-noise.

The children were all residents of NZ's largest city and were assessed using a standardised test of phonological processing (CTOPP-2). Three subtests of the CTOPP-2 were used to obtain a PACS: the dependent variable. Literacy, the ability to use the written word to read and spell, was measured using tests of reading fluency, single-word spelling and GPC knowledge. Ability to understand speech in background noise, an important factor in APD, was also measured. The qualitative measure of a parent/caregiver's response to a question regarding the child's history of dyslexia was analysed. This study was interested firstly in whether the children had phonological awareness difficulties, and secondly whether phonological difficulties were related to the literacy and speech-in-noise measures. Having a more thorough understanding of phonological awareness and literacy abilities will inform intervention for children with APD.

The findings from this study support the hypotheses 1) that school-aged children with APD have phonological awareness difficulties and 2) that phonological awareness difficulties are associated with measurable literacy difficulties including a parent report of dyslexia and/or speech-in-noise measures. The findings will be discussed in detail in relation to the literature on these topics.

8.1 Phonological Awareness Difficulties in School-Aged Children Diagnosed with APD

The children's mean score of phonological awareness ability was below average at 84.17 with a mean percentile of 18. The trend of distribution was across the lower percentile ranks (range is 1 to 63). This suggests these children with APD had a lower ability on phonological awareness tasks as judged by the chosen psychoeducational test (CTOPP-2). This is useful knowledge for an SLT planning next assessment steps for a child presenting with a diagnosis of APD. The presence of phonological awareness difficulties within this cohort could add strength to the auditory deficit theory of dyslexia, which proposes that problems identifying, discriminating and manipulating phonemes are related to APD. The literature claims that by their mean age (range 7 to 10, mean 8.08) the children in this study should have developed the more complex phonological awareness skills needed to be successful in literacy: either by being successful in the act of reading and/or by being taught reading skills. The literature (Chafouleas et al.,1997; Duncan & Johnston, 1999) tells us most children have reached a level of mastery of phonological awareness skills by the age of 7 but that was not the case for the children in the current study who were struggling to be proficient users of phonological awareness. Certainly, the expected level of mastery with the more complex phonemic skill level was not present in this study's school-age group.

8.2 Phonological Awareness Difficulties Associated With Measurable Literacy Difficulties

Results partially support hypothesis 2 that phonological awareness difficulties are related to literacy and speech-in-noise measures in school-aged children with an APD diagnosis, but only for the literacy measures. In particular, reading fluency and parent/caregiver report of dyslexia were the strongest predictors of underlying phonological awareness difficulties. This knowledge is useful for SLTs planning intervention for children diagnosed with APD. Such a child usually presents with the audiologist's diagnostic report. The APD test results can be difficult for anyone other than a specialist audiologist to translate into the functional challenges being experienced by the child. However, the audiologist's report may mention a history of dyslexia and recommend phonological therapies as per published guidelines (Keith et al., 2019). Given such case information as this, a SLT should conduct a test of reading fluency to confirm dyslexia and, for the purposes of measuring progress from subsequent treatment, establish a baseline measurement of reading ability. The literature suggests typically developing school-aged children reduce their reliance on phonological awareness skills and begin to recruit alternative cognitive skills to read fluently (Reis et al, 2000; van Viersen et al., 2019). However, it would appear that many of the children assessed in the current study had not yet developed adequate phonological awareness and/or recruited other cognitive skills to support their reading fluency.

The findings from this study suggest that for school-aged children with APD, a test of phonological awareness could identify deficits and indicate the level of skill breakdown. The literature generally supports that children progress through levels of phonological awareness skill development so targeting the appropriate level for therapy is important. It seems children with APD may have more difficulty acquiring phonological awareness but still require it to develop proficient reading. The school-aged children (aged 7 to 10) in this study had poorer reading fluency which was related to underlying difficulties in phonological awareness.

Statistically significant correlations between phonological awareness difficulty and single-word spelling and GPC were discovered. This suggests to the practising SLT that assessment and then possibly therapy for these literacy skills would also be warranted. The literature in reading science supports therapy for phonological awareness to improve both spelling and GPC skills.

Kilpatrick (2015) and Gillon (2019) are among others in the reading research community who actively advocate for phonological awareness testing as part of the test battery for assessing reading abilities. Judging by this study's findings, it seems that phonological awareness testing may be a useful test inclusion for children diagnosed with APD. Previous research has used individual and/or a combination of phonological awareness measures from the CTOPP/CTOPP-2 and/or similar tests (Bhat, Griffin & Sindelar, 2003; Bonacina et al., 2019; Watson et al, 2003). Although the CTOPP-2 is an assessment of the wider concept of phonological processing, rather than specifically phonological awareness, in its favour the CTOPP-2 collects data on three subtests of phonological awareness and does provide a solid measure of overall phonological awareness by calculating a composite score from these. The CTOPP-2 does not measure response time, but Kilpatrick (2015) recommends a timed test of phonological awareness for older school-aged children. A timed test is sensitive to the detection of compensated phonological awareness problems. A child who is not proficient in phonological awareness usually mentally spells words first in order to find a GPC and will take longer with the task.

This study's findings support the literature in the reading sciences which correlates phonological awareness difficulties with literacy outcomes. It also supports the literature in the hearing sciences which has found a link between phonological awareness and reading fluency in the school-aged APD population (Sharma et al., 2018).

8.3 Age of Diagnosis for APD

Age of diagnosis is important when considering the impact of the child's auditory neural maturation; language, cognitive and attention abilities; especially for participation in the testing situation. The age range of children in the current study was 7 to 10 years (mean age 8.08) and all children met the requirement that diagnosis was made in the 15 months prior to participation. Therefore, most of the children were diagnosed with APD after they turned 7 years of age. Historically, the recommended minimum age at which APD could be diagnosed was 7 years of age (Geffner & Ross-Swain, 2019), the age for which many tests of APD are standardised. Recently the *New Zealand Guidelines on Auditory Processing Disorder* (Keith et al., 2019) suggested that by utilising alternative tests and the clinical judgement of the audiologist it is possible to make a preliminary diagnosis of APD at an earlier age.

8.4 Ethnicity as a Possible Influence of APD and Literacy Abilities

This study had a small sample size, of which 96% (n=29) were identified by their parent/caregiver as being NZ European/Pākehā ethnicity. Ninety-six percent is considerably higher than the actual percentage of NZ European/Pākehā resident in NZ, which Statistics NZ (2013) lists as 59% of the population. Five of the NZ European/Pākehā had dual ethnicity including Samoan, Tongan, South African, Chinese or Argentinian. A total of 13% of the sample identified as having a Pacific ethnicity (in addition to NZ European/Pākehā) which is close to the overall percentage of Pacific peoples in Auckland of 14.6%.

Recent Auckland-based research by Purdy et al. (2018), of 920 11-year-old Pasifika children, used the AAA (2010) clinical criteria, and found a third of the children met the criteria for a diagnosis of APD. This is a higher incidence rate when compared to Esplin and Wright's (2014) estimated NZ prevalence of 6.2%. Purdy et al.'s (2018) findings would suggest that some ethnicities may have a higher incidence of APD. Another factor influencing the higher incidence of APD could be that, as Purdy et al. stated, it is not always possible to use test norms gathered from a Pasifika population, due to a lack of availability of these norms.

In addition to high rates of APD, research has told us that Pasifika children in NZ have high rates of reading and spelling problems. In their study of 59,760 school-aged Pasifika children in the NZ school system, Schluter et al. (2018) found that 11.5% had received interventions for literacy problems. Of particular interest to the current study's Pasifika-Pākehā children was Schluter et al.'s finding that Pasifika children with dual ethnicity were less likely than their Pasifika peers to need literacy interventions.

No participants identified as Māori, which does not reflect the population of Auckland, where 10.7% identify as Māori. It would have been useful to compare phonological awareness performance in Māori children because one NZ study, by Harris (1999), found that Māori children drew less on their knowledge of phonemic awareness than larger chunks of sound such as syllables when learning to read. If thoughtfully designed, however, Gillon and Macfarlane (2017) have shown that interventions can have an impact on multicultural classrooms. In their recent research designed to influence literacy outcomes in classrooms, Gillon et al. (2017) found that children who identified as Māori or Pasifika (45.5% of the cohort) improved in similar ways to children who identified as NZ European. The intervention succeeded in accelerating children's ability to use phonological awareness skills to decode novel words (treatment effect size d = 0.88). The findings have important implications for designing successful teacher-implemented interventions to support children who enter school with known challenges for their literacy learning (Gillon et al., 2019).

8.5 The Literacy Abilities of School-Aged Children Diagnosed with APD

This study found that school-aged children with APD have literacy difficulties. Descriptive analysis shows that this group of school-aged children with APD were not normally distributed across the measures of reading fluency, single-word spelling and GPC knowledge. This would suggest these children diagnosed with APD have less ability in literacy than the general population.

A high proportion of the participants were identified by their parent/caregiver as having a diagnosis/difficulty with literacy/reading/spelling (or dyslexia). This is much higher than the general population where the reported prevalence of dyslexia can vary, depending on the criteria used, from 4–6% (Schulte-Körne & Remschmidt in Neef et al, 2016) to as high as 20% (Shaywitz, 2003). However, the lack of a unifying diagnostic criteria and the heterogeneous nature of both auditory processing and dyslexia adds to the confusion when seeking a connection between the disorders. Furthermore, caution must be exercised when seeking this connection as de Wit et al. (2016) showed in their systematic review. The children in the current study performed poorly on phonological awareness and literacy measures not unlike like de Wit's findings that children diagnosed with APD perform equally poorly on tests of language, cognition and attention. A strength in the current study's design was that it combined quantitative and qualitative data. The parental/caregiver report of dyslexia allowed the parent's voice to be heard alongside the quantitative data, in a design focused on providing clinically applicable information. This study's mixture of methods was not evenly balanced for interpretation (Irwin, Pannbacker, & Lass, 2008). So research specialists such as Wendy Best (cited in Irwin, Pannbacker & Lass; 2008) rightly state that a small amount of qualitative data (such as in this study) means the quantitative data takes a more dominant role. Nonetheless, although only one response from a qualitative checklist was used in this study's analysis, the parental/caregiver report of dyslexia (66% of the responses were affirmative) helpfully *elaborated* the findings of the quantitative data which showed a high incidence of reading problems: 47% were below average for reading fluency and 47% were below average for single-word spelling—with 13% of the spellers being in the critically low range (bottom 10%). In addition, all participants were in the bottom 50th percentile range for GPC knowledge, and the mean percentile for phonological awareness ability was 18 with the majority of the children being distributed below the 40th percentile. There is cross validation of the qualitative and quantitative results which illustrates a high proportion of school-aged children with APD have current and/or reported history of dyslexia, poor reading fluency, spelling, and awareness and GPC knowledge problems.

Assessment of phonological awareness and literacy-skills were comprehensive and conducted on every child in the sample. This was important for analysis of the data but it was also clinically helpful information which the researcher was able to share with the parent/caregiver. Detailed written feedback in the form of a report (Appendix O) was provided to all the parents/caregivers, who in turn could choose to share this with the child's school and other professionals who may be involved. This meant SLTs could interpret the results from the written report and plan interventions for phonological awareness and dyslexia. A further strength of this study was that the commonly used assessment tools, which can be accessed by SLTs in NZ (and Australia, USA and UK). The test selection also allows for easy replication of the assessment battery in future research.

8.5.1 Reading fluency and spelling of single words.

Sharma et al. (2009) used the WARP to measure reading ability but, unlike the current study, used the term reading disorder, rather than dyslexia. Sharma et al. used Pogorzelski and Wheldall's (2002) combined phonological awareness and reading-fluency measures to define a child as having a reading disorder. This meant their school-aged sample had reading accuracy and fluency 1 SD or more below age peers *combined* with phonological awareness scores on at least two subtests of the QUIL 1 SD or more below the mean. By contrast, the current study used the term dyslexia to describe the reading difficulties in the sample, for two reasons 1) to focus on the phonological awareness connection to reading acquisition and difficulties and 2) to avoid possible connections with DLD that problems in reading comprehension may suggest. Despite differing definitions of reading problems, this study is similar to Sharma et al.'s (2009) in finding a high incidence of comorbid reading difficulties in children diagnosed with APD. The incidence of below-average reading fluency for this sample is higher at 47% than Sharma et al.'s (28%). Sharma et al.'s lower incidence was possibly due to a more rigorous and specific method of defining and measuring reading disorder. The current study, despite using different measures to Sharma et al. (2018), also found a high incidence of below-average spelling (Sharma et al., 2018). It should be noted that Sharma et al. (2018) investigated spelling by using a non-word, rather than a single word test.

A possible reason for a higher incidence of children with dyslexia, below-average reading fluency and single-word spelling in in this study is the recruitment methodology used. Recruitment information indicated that the treatment to be used was beneficial for children with suspected reading/spelling/literacy problems. Undoubtedly, the wording of this recruitment information skewed the sample to those for whom reading/spelling/literacy was a problem. This study's findings could equally add strength to the literature which has found children with APD have a high incidence of reading difficulties (Sharma et al., 2009).

8.5.2 GPC knowledge.

A weak to moderate relationship between phonological awareness and GPC knowledge was found in this sample of school-aged children diagnosed with APD. GPC is a cornerstone skill to developing reading and the NZ Ministry of Education has a recently renewed focus on GPCs, alongside general phonological awareness development, within its literacy curriculum (Carroll et al, 2014). The LeST is easily available from an online test-resource site, has been found to have high test–retest, inter-rater reliability and appropriate criterion validity. So SLTs and other literacy specialists may find this Australian test a useful addition to their clinical assessment toolkit. Results from the LeST are clinically useful by indicating the absent GPCs to target in therapy for dyslexia. A possible weakness of the LeST is that the statistically most common pronunciation associated with a grapheme is considered a correct response. Since many multi-graphemes may have more than one possible pronunciation, the test does not allow the child to select a different (and correct) variant of the most common pronunciation e.g., "oo" can be said as a short vowel /ʊ/ or long vowel /u/. The LeST is also not normed on a NZ population and the percentiles and z-scores are provided for Australian school grades, so the SLT will need to translate to the equivalent age range for NZ children (Larsen et al., 2015). In addition, there seems to be no other research on the use of LeST within the APD literature. Despite measuring GPC knowledge, the current study did not measure word level decoding skills, arguably a more functionally relevant measure for literacy ability. The literature in reading science and adaptations of the SVR (see Figure 4) identify difficulty decoding as key to identifying dyslexia. Sharma et al. (2006) measured decoding usiing non-words as a functional measure of GPC; because non-words are novel to children, they must use GPC rules to decode them (Castles et al, 2009). However, this study recognised that true GPC relies only on identification of the phonemes, and a limitation of using non-words is that they rely on other cognitive skills to accurately decode them. Decoding involves other processing and cognitive skills because the child needs to be able to not only identify the phonemes, but group and blend them.

8.7 Auditory Processing Disorder Tests

The current study found, for this sample anyway, that the speech-in-noise test was not a useful predictor of phonological awareness difficulties. Many of the children experienced difficulty hearing speech in noise, with 30% having significant difficulty hearing speech in noise, 40% having more difficulty (than average) and 30% having average ability to hear in noise. The literature suggests that difficulties listening in background noise is a common presenting complaint associated with APD, yet a speech-in-noise measure was not often included in the behavioural tests selected by audiologists for this sample. Tests of speech perception in background noise are used in the aided peripheral hearing communities but the clinical utility of these tests has not been embraced by audiologists for the APD population. This could be because the SIN tests are not appropriate and/or sufficiently sensitive to measure speech-in-noise ability in children with APD. The BKB-SIN was not used by any of the diagnosing audiologists in this sample; they opted for a SCAN-3 test instead. The BKB-SIN vocabulary was possibly not used by NZ children, being American vocabulary or slightly old-fashioned e.g., “store” for shop (Appendix P). Another consideration to the utility of this test would be the listening accessibility of the pre-recorded American accent of the stimuli on the NZ children.

No doubt clinical judgement was used by the audiologists and congruent with the literature, there were a variety of behavioural APD tests used to diagnose APD in this sample of children (Table 14). In keeping with NZ research by Kelly (2007), FPT was a commonly used test. FPT has previously been identified as a test sensitive to functional outcome measures such as spelling and reading ability (Sharma et al., 2019). The next most commonly applied tests in this study, in order of preference, were: Dichotic Words, LiSN-s (the sentences subtest), and the Random Gap-Detection Test. It seems, from this study’s findings, that the Dichotic Words test has now superseded DDT as a preferred test of dichotic listening - Kelly (2007) reported DDT was the most commonly used behavioural test of APD in NZ. The predominance of DWT and LiSN-S within the APD test battery could suggest a shift in preference from non-speech stimuli testing to more language-based measures within the currently used APD test battery in NZ.

Considering the wide-ranging number of tests for diagnosing APD internationally, and the rarity of being diagnosed with the condition in NZ, the baseline for this sample’s APD diagnosis was relatively uniform. All 30 children met the AAA criteria for a diagnosis of APD by their audiologist, and all had a recent diagnosis (in the 15 months prior to participation) yet figure 22 illustrates varying pass/fail percentages across tests. Children with APD are often described as a heterogeneous group (Bellis, 2007; Geffner & Ross-Swain, 2019; Sharma et al. 2009) and recently Wilson (2019) helpfully suggested using a *spectrum approach* to improve understanding of the condition and for classification of severity. At one end of the spectrum would be children who have ‘listening difficulties’ through to those at the opposite end of the spectrum who have a specific disorder of auditory processing. Wilson suggested fewer children have APD than is currently indicated by the use of the broad behavioural-assessment battery which has been adopted for use. Despite Wilson’s suggestions, it was assumed that all the participants had a specific disorder of auditory processing.

8.8. Limitations of this Study

Five limitations have been identified in this study. They are each discussed below.

The high proportion of parent/caregiver reports of dyslexia can be accounted for, in some part at least, by the self-selection process of parents/caregivers, and a general weakness in the recruitment methodology of this study. Parent/caregivers of children with dyslexia were potentially attracted to participating because the recruitment advertisement for the PPT stated the phonological awareness therapy was a treatment for reading/spelling difficulties. The parent/caregiver was potentially made aware by the diagnosing audiologist that phonological awareness therapy was a treatment they sometimes recommended for APD. In addition, and in all likelihood, self-selection skewed the sample to those participants who had a supportive parent, who had access to transport and time to bring them to the clinic for assessment. This was perhaps balanced somewhat by the fact that, despite an APD diagnosis, the participants selected participation in the PPT intervention programme rather than other perhaps more costly treatments.

A second possible weakness was the selection of a single-word spelling test rather than one which used non-words. Arguably, spelling of non-words would have assessed the child's phonological encoding ability rather than the SAST real words test (Sharma et al., 2018). A suggestion would have been the QUIL (Dodd et al., 1996) subtest of spelling non-words used by Sharma et al. (2018). Four children in the sample had a critically low score which is concerning considering that this category represents the score below which only 10% of the age group should be scoring.

The study did not reflect the ethnicities living in Auckland. A third weakness in this study was the absence of any participants who identified as Māori, when the percentage of the population in Auckland is actually 10.7%. Statistics NZ (2013) lists 59% of Auckland's population identifies as NZ European/Pākehā so this study had disproportional representation at 96%. In its favour this study had 13% of the sample who also identified as having a Pacific ethnicity in addition to NZ European/Pākehā—Statistics NZ list 14.6% of Auckland's population as Pasifika.

A fourth weakness is that the assessments used were not designed or standardised on a NZ population, which calls into question the reliability of the findings. NZ samples have scored below the means for published data from North American tests so this may also be the case for the CTOPP-2 (Barker-Collo, 2001; Johnson, 2009; Paulin & Purdy, 2008), especially given that the Blending words subtest has an audio recording in an American accent. The fact that the single-word spelling (SAST) and reading fluency (WARP) used Australian school-grade norms meant that test scores needed to be adapted for use with the NZ population. Both reading fluency and single-word spelling tests were Australian curriculum-based measures which means the child's score is conventionally evaluated against their school grade/level (number of years at school). The WARP analyses the child's raw score by counting the number of terms the child has been at school, to obtain a score, not their age. Arguably, because children in Australia start school later than in NZ, and have had less time exposed to reading instruction, these tests could be deemed under sensitive for children in this study because NZ children should have had more years at school than their Australian peers.

The reading-fluency measure showed a moderate correlation and could be a useful screening tool for phonological awareness; a more comprehensive measure of the children's reading abilities would have included single words and non-words. In terms of dyslexia, a measure of reading which included non-words would arguably provide more information about the child's phonological decoding abilities. Sharma et al. (2009), using Coltheart's dual-route model of reading, suggest that reading real words requires accessing both phonological and semantic systems (the child's lexicon) whereas non-words require access to only the phonological system (to map graphemes onto phonemes) for decoding purposes. A suggested test would be The **Castles** and Coltheart **Test** 2 (Castles & Coltheart, 1993) which includes regular, irregular and non-word reading. However, the current study used a GPC test which drew attention to the children's ability to apply their phonological knowledge of graphemes.

Equally, spelling measures should have included words and non-words to measure phonological ability. In addition, the SAST test form used had an error, so, for number 13, the children were asked to spell “toy” rather than the actual target “the.” Also, as recommended by the authors, three passages of the WARP should have been administered instead of just one, providing a more reliable measure of reading fluency (the average number of words across the three passages that the child could read correctly in a minute).

8.11 Implications.

There is a growing awareness in NZ schools about the importance of phonological awareness to literacy acquisition and its usefulness in ameliorating dyslexia. SLTs are skilled in phonological awareness assessment and treatment. SLTs are also asked to be involved to provide phonological awareness treatment for children with APD. This study shows that school-aged children with APD have a high incidence of phonological awareness problems associated with poor literacy. Parent/caregiver reports show a high incidence of dyslexia within this group. There are a number of implications for practice highlighted by this research.

The three aspects are:

1. The need for children diagnosed with APD to be considered for assessment of their phonological awareness, reading fluency, spelling and GPC knowledge skills.
2. The need for children diagnosed with APD to be considered for phonological awareness therapy.
3. The need for the child to be referred to a SLT for assessment and treatment of literacy-related difficulties, if a suspicion of APD has been indicated.

CHAPTER 9. Conclusion

The findings of this study showed a coherent relationship between phonological awareness difficulties and literacy measures in school-aged children diagnosed with APD. There was a medium to strong relationship between phonological awareness difficulty and reading fluency and parent/caregiver report of dyslexia. This is unsurprising given that fluency of reading is dependent on proficient decoding, and subsequent reading fluency. In addition, phonological awareness and GPC are foundation skills for decoding. For this sample of children diagnosed with APD, small and select as it was, there is a high incidence of concomitant dyslexia. Past literature has shown that reading difficulties are commonly associated with APD. This study found phonological awareness difficulty was also associated with the related literacy areas of spelling and GPC ability. Phonological awareness difficulty was not related to an APD test for speech-in-noise.

SLTs in the field should use tests of reading fluency and parent/caregiver's reports of dyslexia as potential indicators of underlying phonological awareness difficulties in children with APD. Consequently, phonological awareness difficulties should be targeted by therapy and comprehensive management strategies to support literacy.

Caution must be exercised when applying the findings of this study to all populations with APD and dyslexia. Auditory processing and reading difficulties are multifactorial systems by nature. Linear and hierarchical models of auditory processing relating it to reading disorders are convenient, but it is recommended that the role of neurophysiological, cognitive and psychological processing systems also be considered in management of the condition. The same recommendation can be applied to simplifying dyslexia diagnoses and management.

9.1 Future Research

This study shed light on the relationship between phonological awareness difficulties and literacy measures in children diagnosed with APD. However, all of the data have not been analysed and so the relationship between the APD test results and literacy test results has not yet been considered. A useful next step would be to explore APD tests results (see Figure 22) in relation to phonological awareness, reading fluency, spelling and GPC test results. Similar to Sharma et al. (2018), this study found that reading fluency was associated with better phonological awareness. However, further analysis of results may lead to similar conclusions to those reached by Sharma et al (2018), that reading fluency was also associated with better FPT scores (on the APD test battery) and older age.

Future analysis of this study's data could also calculate correlations for individual phonological awareness subtests, in particular elision (phoneme manipulation) and reading fluency. It would be interesting to determine if findings were similar to that of Sharma et al. (2009) who, in their study of 68 school-aged children with APD, found that only phoneme manipulation correlated with reading fluency (using a subtest from the QUIL) (Dodd et al., 1996). Sharma et al. used the QUIL "phoneme manipulation" task which is similar to the Elision CTOPP-2 subtest in that the respondent is required to remove a phoneme from a word to create a new word (e.g., Say “split,” now say “split” without saying /p/). It would be interesting to explore whether phoneme manipulation/elision as a phonological awareness skill might be a useful measurement for older school-aged children who have been diagnosed with APD. Kilpatrick (2015) recommended phoneme manipulation assessment for the older school-aged child because it has been shown to be a sensitive predictor of reading ability. Kilpatrick’s aforementioned timed phonological awareness test may be worth investigating in future research for use with the older school-aged group commonly diagnosed with APD.

Future research should be conducted within a culturally appropriate framework. The lack of acknowledgement of cultural identity during this study has likely caused negative consequences on the participants (Dudley, Wilson, & Barker-Collo, 2014). Using a more culturally appropriate research design would also increase the relevance of the findings to New Zealanders of all cultures (Gillon & McFarlane, 2017; Harris, 2007).

Appendices

Appendix A. Seven Studies Involving Auditory Processing Disorder Which Used Phonological/Phonemic Awareness Tests in School-Aged Children

Author	**Sample Size**	**Age of children**	**Control group (*N*)**	**Auditory processing tests used**	**Phonological awareness tests used**
De Martino, Espesser, Rey and Habib, 2001	13 phonological dyslexics	10-13	10	Temporal order judgement TOJ) using the succession of two consonants in a cluster (/p/-/s/)	Phoneme deletion Rhyme judgement Nonword spelling (simple and complex)
Kuppen et al., 2011	95	M = 94.3 months	55	Amplitude rise time tasks Discrimination tasks of: frequency, intensity, rhythm	Phonemic decoding
Sharma, M., Purdy, S., & Kelly, A. (2009)	68	8-12 years		-DDT -FPT -RGDT -Compressed and reverberant words test - Masking level difference	Queensland University Inventory of Literacy phonological awareness subtests - auditory rhyming - spoonerisms - phoneme detection - phoneme segmentation - phoneme manipulation
Sharma, M., Purdy, S., & Kelly, A. (2012)	55	7 to 13 years	12	FPT Monaural low redundancy	Queensland University Inventory of Literacy phonological awareness subtests - auditory rhyming - spoonerisms - phoneme detection - phoneme segmentation - phoneme manipulation
Sharma, Cupples & Purdy, 2018	90	7-13 years		-DDT -FPT) -RGDT -Compressed and reverberant words - Masking level difference	

Walker, Hall, Klein & Phillips, 2006	120	7 years of age to adulthood		Temporal processing tasks	CTOPP Elision and Blending words subtests
Zhang & McBride, 2014	180 typically developing readers – Chinese speakers	6.92 9.41 years	N/A	-Amplitude detection task -Rapid frequency discrimination task -Frequency discrimination task	Initial phonemic deletion task adapted for Chinese language from CTOPP-2

Appendix B Ethics Approval

Research Office
Post–Award Support Services

The University of Auckland
Private Bag 92019
Auckland, New Zealand

Level 10, 49 Symonds Street
Telephone: 64 9 373 7599
Extension: 83711
Facsimile: 64 9 373 7432
ro-ethics@auckland.ac.nz

UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE (UAHPEC)

23-Aug-2017

MEMORANDUM TO:

Prof Suzanne Purdy
Psychology

Re: Application for Ethics Approval (Our Ref. 019449): Approved with comment

The Committee considered your application for ethics approval for your study entitled **Phonological Processing Treatment: Diagnosis and Remediation of Auditory Processing Disorder in Children.**

Ethics approval was given for a period of three years with the following comment(s):

1. PIS Parent – not from SoundSkills Clinic please ensure that the University of Auckland postal address and departmental name and address is showing on the first page of your document. Please remove information in the footer section of this document.

2. PIS Parent – from SoundSkills Clinic – please ensure that the departmental name and address details shows only on the first page and not all pages of the document. Please remove information in the footer section of this document.

The expiry date for this approval is 23-Aug-2020.

If the project changes significantly you are required to resubmit a new application to UAHPEC for further consideration.

If you have obtained funding other than from UniServices, send a copy of this approval letter to the Activations team in the Research Office, at ro-awards@auckland.ac.nz. For UniServices contracts, send a copy of the approval letter to the Contract Manager, UniServices.

The Chair and the members of UAHPEC would be happy to discuss general matters relating to ethics approvals if you wish to do so. Contact should be made through the UAHPEC Ethics Administrators at ro-ethics@auckland.ac.nz in the first instance.

Please quote Protocol number **019449** on all communication with the UAHPEC regarding this application.

(This is a computer generated letter. No signature required.)

UAHPEC Administrators
University of Auckland Human Participants Ethics Committee

c.c. Head of Department / School, Psychology
Mrs Lucy Sparshott
Dr William Keith
Mrs Melissa Baily

Additional information:

1. Do not forget to fill in the 'approval wording' on the Participant Information Sheets, Consent Forms and/or advertisements, giving the dates of approval and the reference number. This needs to be completed, before you use them or send them out to your participants.

2. At the end of three years, or if the study is completed before the expiry, you are requested to advise the Committee of its completion.

3. Should you require an extension or need to make any changes to the project, please complete the online Amendment Request form associated with this approval number giving full details along with revised documentation. If requested before the current approval expires, an extension may be granted for a further three years, after which time you must submit a new application.

Appendix C Child Assent Form

Speech Science
School of Psychology, Faculty of Science
THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Email: l.sparshott@auckland.ac.nz

Child Information Sheet and Assent Form

THIS FORM WILL BE HELD FOR A PERIOD OF SIX YEARS

Project Title: Phonological Processing Treatment: Diagnosis and Remediation of Auditory Processing Disorder in Children

Researchers: Lucy Sparshott, Suzanne Purdy, William Keith, Melissa Baily, Clare McCann, Jane Carroll

- We are asking you to help us with some research about listening skills.
- We want your help to find out if a treatment helps your listening skills get better.
- Your parent/caregiver has said it is okay for you to take part in this study.
- We want you to do some short listening, reading and spelling tests.
- We will ask you to listen, say some words and sounds, read and spell. All this will take about 2 hours.
- We will ask you to do the same tests again after the treatment.
- We will also ask to come see you at school or home or you will come into the clinic for an hour once a week for up to 15 weeks to learn more about the sounds that make up words. We will play some games with letters and sounds and you might take some homework home to practice.
- You are allowed to ask me questions if you feel unsure.
- If you decide later that you don't want to do this with us anymore, we can stop at any time.

- ★ I understand that I will be asked to repeat words, sounds, read and spell.
- ★ I understand that I will be asked to do the same test again at another time.
- ★ I know that I can tell the researcher if I do not want to do the tests or answer the questions anymore without giving a reason and that this will be fine.
- ★ I understand that the researchers will not use my name when they talk about the study or when they write about the study.
- ★ I understand that it is my choice to take part in this study or not. If I choose not to nobody will mind.
- ★ I agree to take part in this research study.

If you would like to do this, write and sign your name on the line below.

My name is ___________________________________ and I am happy to take part in this study.

Signature: _______________________

The date today is ________________

Thank you ☺

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE ON 23 August 2017 FOR THREE YEARS. Reference number 019449

Appendix D. Child Assent Form Including APD Testing

Speech Science
School of Psychology, Faculty of Science
THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Email: l.sparshott@auckland.ac.nz

Child Information Sheet and Assent Form

THIS FORM WILL BE HELD FOR A PERIOD OF SIX YEARS

Project Title: Phonological Processing Treatment: Diagnosis and Remediation of Auditory Processing Disorder in Children

Researchers: Lucy Sparshott, Suzanne Purdy, William Keith, Melissa Baily, Clare McCann, Jane Carroll

- We are asking you to help us with some research about listening skills.
- We want your help to find out if a treatment helps your listening skills get better.
- Your parent/caregiver has said it is okay for you to take part in this study.
- Firstly we *may* need you to do a listening and problem-solving tests which will take up to 2 ½ hours.
- Once they are done you may come back to do some short listening, reading and spelling tests. We will ask you to listen, say some words and sounds, read and spell. All this will take about 2 hours.
- We will ask you to do the same tests again after the treatment.
- We will also ask to come see you at school or home or you will come into the clinic for an hour once a week for up to 15 weeks to learn more about the sounds that make up words. We will play some games with letters and sounds and you might take some homework home to practice.
- You are allowed to ask me questions if you feel unsure.
- If you decide later that you don't want to do this with us anymore, we can stop at any time.

- I understand that I will be asked to repeat words, sounds, read and spell.
- I understand that I will be asked to do the same test again at another time.
- I know that I can tell the researcher if I do not want to do the tests or answer the questions anymore without giving a reason and that this will be fine.
- I understand that the researchers will not use my name when they talk about the study or when they write about the study.
- I understand that it is my choice to take part in this study or not. If I choose not to nobody will mind.
- I agree to take part in this research study.

If you would like to do this, write and sign your name on the line below.

My name is ___________________________________ and I am happy to take part in this study.

Signature: _______________________

The date today is ________________

Thank you ☺

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE ON 23 August 2017 FOR THREE YEARS. Reference number 019449

Appendix E Consent Form for Parents at SoundSkills

SCIENCE
SCHOOL OF PSYCHOLOGY

Speech Science
School of Psychology, Faculty of Science
THE UNIVERSITY OF AUCKLAND
NEW ZEALAND

CONSENT FORM FOR PARENTS/CAREGIVERS

THIS FORM WILL BE HELD FOR A PERIOD OF SIX YEARS

Project Title: Phonological Processing Treatment: Diagnosis and Remediation of Auditory Processing Disorder in Children

Researchers: Lucy Sparshott, Suzanne Purdy, William Keith, Melissa Baily, Clare McCann, Jane Carroll

- The research project has been explained to me and I understand the purpose of my (and my child's) participation. I have had the opportunity to ask questions and have them answered to my satisfaction.
- I have read and I understand the information sheet.
- I understand that researchers may access information from my child's clinical files at SoundSkills clinic to obtain background information required for the study.
- I understand that my child will be required to attend a testing appointment at SoundSkills for approximately 2 hours on two or three occasions.
- I understand that my child will be asked to do tests for: phonological processing skills, reading, spelling, and hearing for complex speech.
- I understand that my child, my child's teacher and I will be asked to complete a questionnaire that will take approximately 10-15 minutes to complete on two or three occasions.
- I understand that the researchers may ask the school to provide recent academic performance scores for my child. I understand that my child will be randomly assigned to one of three therapy groups.
- I understand that the therapy will involve my child attending SoundSkills clinic include 'at home/school or' SoundSkills for an hour per week for up to 15 weeks.
- I understand that it is my choice and my child's choice to participate or not to participate and this will not affect my child's eligibility to attend the SoundSkills Clinic.
- I understand that I may withdraw my information and my child's information from the study up to three months after completion of the treatment by contacting one of the researchers listed above. If I do withdraw this will in no way affect my relationship with SoundSkills or the University of Auckland, and all information relating to my and my child's participation will be withdrawn and will not be included in any reports.
- I understand that if the information I and my child provide is reported/published,

this will be done in a way that does not identify me or my child as its source.

- I understand that consent forms and information collected during this study will be stored in locked filing cabinets at the University of Auckland and electronic data will be stored on a password protected University of Auckland computer, backed up by a server. Data will be destroyed after a period of six years by shredding and deleting computer and audio files. De-identified results may be kept in a spreadsheet indefinitely.
- I know whom to contact if I have any questions about the study.

If you would like to participate, please complete this form and email it to the researcher return it in the enclosed envelope.

I __________________________________(parent/caregiver full name) agree to participate in this study.

Consent of participants under 16 years is to be obtained through a parent or legal guardian. I, the parent/legal guardian of ____(child's first and last name) agree for my child to participate in the study.

I agree to my child's teacher being asked to participate in this research: Yes/ No

I agree to my child's academic performance scores being released to the research team Yes/No

(If your answer is yes please provide the name of your child's teacher and school)

Teacher's name and School:

____

I would like to receive a summary of the research upon completion: Yes / No

(If your answer is yes please provide an email address that you would like the summary sent to)

Email Address: ____

Parent/Caregiver name (please print)

____

Parent/Caregiver signature____

Date_________________

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE ON 23 August 2017 FOR THREE YEARS. Reference number 019449

Appendix F Consent Form for Parents not at SoundSkills

Speech Science
School of Psychology, Faculty of Science
THE UNIVERSITY OF AUCKLAND
NEW ZEALAND

CONSENT FORM FOR PARENTS/CAREGIVERS

THIS FORM WILL BE HELD FOR A PERIOD OF SIX YEARS

Project Title: Phonological Processing Treatment: Diagnosis and Remediation of Auditory Processing Disorder in Children

Researchers: Lucy Sparshott, Suzanne Purdy, William Keith, Melissa Baily, Clare McCann, Jane Carroll

- The research project has been explained to me and I understand the purpose of my (and my child's) participation. I have had the opportunity to ask questions and have them answered to my satisfaction.
- I have read and I understand the information sheet.
- I understand that researchers will require information from my child's APD diagnostic reports, hearing tests and other relevant reports, e.g. from speech language therapists or educational psychologists.
- I understand that the researchers may ask the school to provide recent academic performance scores for my child.
- I understand that my child will be required to attend a testing appointment at SoundSkills for approximately 2 hours on two or three occasions.
- I understand that my child will be asked to do tests for: phonological processing skills, reading, spelling, and hearing for complex speech.
- I understand that my child, my child's teacher and I will be asked to complete a questionnaire that will take approximately 10-15 minutes to complete on two or three occasions.
- I understand that my child will be randomly assigned to one of three therapy groups.
- I understand that the therapy will involve my child attending therapy at clinic for an hour per week for up to 15 weeks.
- I understand that it is my choice and my child's choice to participate or not to participate.
- I understand that I may withdraw my information and my child's information from the study up to three months after completion of the treatment by contacting one of the researchers listed above. If I do withdraw all information relating to my and my child's participation will be withdrawn and will not be included in any reports.
- I understand that if the information I and my child provide is reported/published, this will be done in a way that does not identify me or my child as its source.
- I understand that consent forms and information collected during this study will be

stored in locked filing cabinets at the University of Auckland and electronic data will be stored on a password protected University of Auckland computer, backed up by a server. Data will be destroyed after a period of six years by shredding and deleting computer and audio files. De-identified results may be kept in a spreadsheet indefinitely.

- I know whom to contact if I have any questions about the study.

If you would like to participate, please complete this form and return it in the enclosed envelope.

I ________________________________(parent/caregiver full name) agree to participate in this study.

Consent of participants under 16 years is to be obtained through a parent or legal guardian. I, the parent/legal guardian of ______________________________________(child's first and last name) agree for my child to participate in the study.

I agree to my child's teacher being asked to participate in this research: Yes / No

I agree to my child's academic performance scores being released to the research team Yes/ No

(If your answer is yes please provide the name of your child's teacher and school)

Teacher's name and School: ____

I would like to receive a summary of the research upon completion: Yes / No

(If your answer is yes please provide an email address that you would like the summary sent to)

Email Address: ____

Parent/Caregiver name (please print)____

Parent/Caregiver signature____

Date_________________

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE ON 23 August 2017 FOR THREE YEARS. Reference number 019449

Appendix G Advertisement

Auditory Processing Disorder (APD) can affect children's learning and confidence.

We want to help children with APD and to find better treatments.

How can you help?

We are inviting school aged children and their parents in the Auckland region to help with our research.

Volunteer your time to help us!

What does it involve? We might ask you to fill out a survey or ask your children to participate in some testing or treatment.

If you are interested or require further information, contact:

Melissa Baily: m.baily@auckland.ac.nz
Lucy Sparshott: l.sparshott@auckland.ac.nz

School of Psychology

(Speech Science)

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE ON xxxx for three years, Reference Number 018701
Research funded by the Oticon Foundation (Denmark)

Appendix H Recruitment information for APD research projects

Recruitment information: Auditory Processing Disorder research projects

University of Auckland

*Project 3) Speech Volume Level project

Contact: Melissa Baily m.baily@auckland.ac.nz

We are looking for children aged 7-10 years in Years 3-5 at school diagnosed with APD in the past year.

Children should not have had any treatment for APD and should not be wearing hearing aids.

Participation involves an appointment at University of Auckland for ***approx. 2 hours*** *(and access to clinic file information). Parents will be given a petrol voucher and the child will receive a Westfield voucher.*

We will be testing at a range of volume levels of hearing for speech, auditory memory tests and the auditory brainstem response (ABR) test that measures the response of the hearing nerve and brain pathways to sounds.

*Project 4) Quantifying Disability project

Contact: Melissa Baily m.baily@auckland.ac.nz

We are looking for children aged 5-11 years diagnosed with APD in the past year.

Children should not have had any treatment for APD and should not be wearing hearing aids.

Participation involves two appointments at SoundSkills clinic in Auckland taking approx 30 minutes each.
We will be using parent, child and teacher questionnaires and some tests of hearing for speech in a noisy background to try to measure the effect of APD on everyday life.

*Project 5) Free phonological awareness therapy for children with APD

Contact: Lucy Sparshott l.sparshott@auckland.ac.nz

This will be of high interest to those who wish to trial a treatment that has been shown to be effective with children who have reading/spelling difficulties.

We are looking for children aged 5-9 years old diagnosed or provisionally diagnosed with APD in past year.

Up to 12 weeks FREE! **therapy with a Speech-language Therapist with varying start dates between Feb-July** 2018 (it is a random control trial style research)

Normal range of cognition. Behaviour abilities must allow them to participate in weekly sessions at clinic, home or school. Co-morbidities ok. Participants can not be wearing hearing aids/RMHAs or receiving any other treatment at the time of participation.

Involves a pre-test (2 hours at SoundSkills), up to 12 weeks of therapy (1 hour per week) and a post-test (2 hours at SoundSkills).

***please note children can participate in one or more of these projects if interested.**

Appendix I Brief Overview of PPT

Recruiting now…. don't miss out

The University Of Auckland is conducting research and are able to offer

Free treatment for children with

Auditory Processing Disorder.

Randomised start dates between February to July 2019.

Who: Children aged 5-9 have the opportunity to be involved in treatment offered one-on-one with a Speech therapist in *the home, school or clinic*.

Where: The children will receive weekly appointments at home, school or clinic to receive phonological treatment (which has been shown to be effective for reading/spelling difficulties).

Why: We know this treatment helps children who have literacy difficulties. Help us find out if it helps children with APD.

Children must not be receiving any other treatment at the time of participation in the treatment e.g. Remote Microphone Hearing Aids.

For more information please contact: Lucy Sparshott Speech Language Therapist,

l.sparshott@auckland.ac.nz **phone 09 923 6659/0210 544 929**

Appendix J Information for Parents at SoundSkills

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

SCIENCE
SCHOOL OF PSYCHOLOGY

Speech Science
School of Psychology, Faculty of Science
THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Email: l.sparshott@auckland.ac.nz

PARTICIPANT INFORMATION SHEET FOR PARENTS/CAREGIVERS

Project Title: Phonological Processing: Diagnosis and Remediation of Auditory Processing Disorder in Children

Researchers: Lucy Sparshott, Suzanne Purdy, William Keith, Melissa Baily, Clare McCann, Jane Carroll

The Project

The purpose of this project is to find a useful treatment method for improving the listening skills of children with Auditory Processing Disorder (APD). We want to compare some clinical tests and treatment methods for listening to work out which are the best tools to use with children with APD. In particular we will focus on testing and training phonemic awareness, which is the ability to identify and manipulate the small sounds of speech (phonemes).

The ability to process the more complex parts of a language is called phonological processing. These skills including phonemic awareness, are important for children to learn to read, write and spell well (literacy). Difficulties with phonological processing are often seen for children with APD.

Families with school-aged children who have been diagnosed with APD will be asked to participate.

This research is part of a two-year project that started in September 2016 and will finish in September 2019. It is being conducted in partnership with SoundSkills APD clinic, a specialist centre for diagnosis and treatment of APD, based in Greenlane, Auckland. The Oticon Foundation (Denmark) has provided funding for this research.

Participants

We are looking for children who have a diagnosis of auditory processing disorder (APD), normal audiograms and normal cognitive skills who are aged between 5-9 years old. Your child must have a recent diagnosis of APD (in the past year).

What will be done

We will ask your child to undergo some extra tests including tests of phonological processing skills, listening, reading, and spelling. Your child will be asked to repeat sounds, words, numbers and sentences. She/he will also be asked to read and spell words and discuss the meaning of words and/or short passages.

Testing will be carried out at SoundSkills clinic, The Stichbury Bidwill Centre

251 Campbell Road, Greenlane, Auckland

There will be no charge for the appointment which will last up to 2 hours. If your child has not had a hearing test for some time, her/his hearing will be rechecked prior to testing, as per normal clinic protocol.

All of the tests will be carried out using procedures routinely used in testing children. Testing will be conducted by the researchers and by clinic audiologists who have signed a confidentiality agreement.

We will also ask you to complete a questionnaire about your child's functioning in everyday life. This questionnaire may be available online or in paper format, and will take 10-15 minutes to complete. If you agree, your child's teacher will also be asked to complete a questionnaire about your child's functioning at school. We may also ask your child to complete a questionnaire about her/his experiences of hearing in different environments.

We also would like your permission to access your child's recent academic performance assessment data (the principal of the school's permission will also be gained on a separate form).

After the testing appointment, your child will be randomly assigned to one of three therapy groups. All groups will attend a therapy appointment for approximately 1 hour per week for up to 15 weeks. Two groups will receive therapy immediately with one group receiving therapy with mild amplification (using a headphone device providing extra volume of the therapist's voice). The third group (control group) will receive therapy after a delayed period of 15-20 weeks.

At the end of the 15 week period, all children will undergo repeat testing of the same tests originally performed during the first test appointment. This second test is very important to determine if there has been any change to your child's skills over the 15 week period. This testing will again be carried out at SoundSkills APD clinic at no charge in an appointment lasting up to 2 hours.

Children in the control group will also be asked to repeat testing for a third time after they have received therapy.

The researchers will require information from your child's APD diagnostic reports, hearing tests and other relevant reports, e.g. from speech language therapists or educational psychologists.

Benefits

Your child will receive extra testing of her/his reading, spelling, listening and phonological processing skills. The testing may identify previously overlooked areas of difficulty that can be addressed in treatment or further referral.

Your child will also receive free treatment aimed at improving phonological processing skills which may have a flow-on effect to improve her/his listening for literacy.

Costs

There are no additional charges from SoundSkills or the University of Auckland for your child to undergo these assessments and treatment.

Incidental Findings

There is the potential that the testing and questionnaires may highlight areas that have not been previously detected. The researchers are experienced clinical professionals who will be able to discuss any concerns you may have and will be able to refer if needed. Further audiological support is available through hospital audiology clinics, the University of Auckland Hearing and Tinnitus Clinics and SoundSkills APD clinic.

Confidentiality

The information provided by you, your child and your child's teacher in this study will remain confidential and no information that will identify you, your child or your child's teacher as an individual will be reported in any reports, presentations or publications. Only the researchers will have access to the data files.

Storage of information

Results will be held in a separate place to the research consent forms. Results and consent forms will be kept in a locked filing cabinet on the University of Auckland premises accessible only to the researchers participating in the study. Electronic data will be stored on a password protected University of Auckland computer, backed up by a server. Data will be destroyed after a period of six years by shredding and deleting computer files. De-identified results will be kept in a spreadsheet indefinitely.

Decision to participate and the right to withdraw at any time

Participation is entirely voluntary. If you decide that you, your child and your child's teacher can participate, you are free to withdraw your support for this research at any time without having to give a reason and without consequence. You may withdraw results up to three months after you, your child and your child's teacher begin to participate in the study.

How to Contact Us

If you have any questions, please feel free to contact us (contact details below).

After completion of the study a summary of the findings will be made available on request.

Contact details of researchers

Lucy Sparshott
Research Fellow
Discipline of Speech Science
The University of Auckland
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Auckland 1142
Tel: (09) 923 6659
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Dr William Keith
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University of Auckland
Director
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c.mccann@auckland.ac.nz

Dr Jane Carroll
Senior Researcher
University of Otago
Jane.carroll@otago.ac.nz
Tel: (03) 479 5267

Ethics approval: For any queries regarding ethical concerns you may contact:
The UAHPEC Chair
The University of Auckland Human Participants Ethics Committee
The University of Auckland, Research Office
Private Bag 92019, Auckland 1142
Tel: 09 373-7599 extn. 83711
Email: ro-ethics@auckland.ac.nz

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE ON 23 August 2017 FOR THREE YEARS. Reference number

Appendix K Information for Parents not at SoundSkills

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

SCIENCE
SCHOOL OF PSYCHOLOGY

Speech Science
School of Psychology, Faculty of Science
THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Email: l.sparshott@auckland.ac.nz

PARTICIPANT INFORMATION SHEET FOR PARENTS/CAREGIVERS

Project Title: Phonological Processing: Diagnosis and Remediation of Auditory Processing Disorder in Children

Researchers: Lucy Sparshott, Suzanne Purdy, William Keith, Melissa Baily, Clare McCann, Jane Carroll

The Project

The purpose of this project is to find a useful treatment method for improving the listening skills of children with Auditory Processing Disorder (APD). We want to compare some clinical tests and treatment methods for listening to work out which are the best tools to use with children with APD. In particular we will focus on testing and training phonemic awareness, which is the ability to identify and manipulate the small sounds of speech (phonemes).

The ability to process the more complex parts of a language is called phonological processing. These skills including phonemic awareness, are important for children to learn to read, write and spell well (literacy). Difficulties with phonological processing are often seen for children with APD.

Families with school-aged children who have been diagnosed with APD will be asked to participate.

This research is part of a two-year project that started in September 2016 and will finish in September 2018. It is being conducted in partnership with SoundSkills APD clinic, a specialist centre for diagnosis and treatment of APD, based in Greenlane, Auckland. The Oticon Foundation (Denmark) has provided funding for this research.

Participants

We are looking for children who have a diagnosis of auditory processing disorder (APD), a normal audiogram (pure-tone hearing test) and normal cognitive skills who are aged between 5-9 years old. Your child must have a recent diagnosis of APD (in the past year).

What will be done

APD and cognitive testing may be required for your child if any of the following apply:

- if your child has not previously been tested for APD
- if it has been some time since your child has had an APD diagnosis (more than 15 months)

- if the APD assessment your child received does not meet our criteria
- if your child does not have recent cognitive assessment information.

The cognitive testing requires your child to look at and match patterns (it is a non-verbal test). For the APD testing she/he will be asked to undergo further testing which will require your child to repeat numbers and words. If the cognitive/APD testing shows that your child does not have APD or has a hearing/cognitive disorder then we cannot include her/him in the research project. Your child will then not be eligible to continue in the research project. However, a report will be provided to you after the testing outlining the results and recommending referrals if required. The total testing time will be 30 minutes for hearing testing only or approximately 2 to 2 ½ hours for hearing and APD/cognitive testing.

Once it is clear your child has a diagnosis of APD and does not have cognitive/hearing problems we will ask him/her to attend another appointment to undergo some extra tests including tests of phonological processing skills, listening, reading, and spelling for the research project. Your child will be asked to repeat sounds, words, numbers and sentences. She/he will also be asked to read and spell words and discuss the meaning of words and/or short passages. This testing appointment will last 2 hours.

All testing will be carried out at SoundSkills APD clinic, located at The Stichbury Bidwill Centre, 251 Campbell Road, Greenlane, Auckland

There will be no charge for any of the appointments. All of the tests will be carried out using procedures routinely used in testing children. Testing will be conducted by the researchers and by clinic audiologists who have signed a confidentiality agreement.

We will also ask you to complete a questionnaire about your child's functioning in everyday life. This questionnaire may be available online or in paper format, and will take 10-15 minutes to complete. If you agree, your child's teacher will also be asked to complete a questionnaire about your child's functioning at school. We may also ask your child to complete a questionnaire about her/his experiences of hearing in different environments.

We also would like your permission to access your child's recent academic performance assessment data (the principal of the school's permission will also be gained on a separate form).

The researchers will also require information if available from your child's APD diagnostic reports, hearing tests and other relevant reports, e.g. from speech language therapists or educational psychologists. A brief background history of your child will also be obtained prior to testing.

Please note that we are not able to offer a complete service regarding diagnosis and management of APD for your child as we will only offer the testing that is required for the research project. If you would like to consider APD management options for your child after the study if required, we recommend that you contact SoundSkills clinic.

After the testing appointment, your child will be randomly assigned to one of three therapy groups. All groups will attend a therapy appointment for approximately 1 hour per week for up to 15 weeks. Two groups will receive therapy immediately with one group receiving therapy with mild amplification (using a headphone device providing extra volume of the therapist's voice). The third group (control group) will receive therapy after a delayed period of 15-20 weeks.

At the end of the 15 week period, all children will undergo repeat testing of the same tests originally performed during the first test appointment. This second test is very important to determine if there has been any change to your child's skills over the 15 week period. This testing will again be carried out at SoundSkills APD clinic at no charge in an appointment lasting up to 2 hours.

Children in the control group will also be asked to repeat testing for a third time after they have received therapy.

The researchers will require information from your child's APD diagnostic reports, hearing tests and other relevant reports, e.g. from speech language therapists or educational psychologists.

Benefits

Your child may receive extra testing of her/his hearing, auditory processing, cognitive, reading, spelling, listening and phonological processing skills. The testing may identify previously overlooked areas of difficulty that can be addressed in treatment or further referral. You will receive a report outlining the results of the hearing and APD testing (if undertaken) and recommending any referrals if required.

If your child meets the inclusion criteria he/she will also receive free treatment aimed at improving phonological processing skills which may have a flow-on effect to improve her/his listening for literacy.

Costs

There are no additional charges from SoundSkills or the University of Auckland for your child to undergo these assessments and treatment.

Incidental Findings

There is the potential that the testing and questionnaires may highlight areas that have not been previously detected. The researchers are experienced clinical professionals who will be able to discuss any concerns you may have and will be able to refer if needed. Further audiological support is available through hospital audiology clinics, the University of Auckland Hearing and Tinnitus Clinics and SoundSkills APD clinic.

Confidentiality

The information provided by you, your child and your child's teacher in this study will remain confidential and no information that will identify you, your child or your child's teacher as an individual will be reported in any reports, presentations or publications. Only the researchers will have access to the data files.

Storage of information

Results will be held in a separate place to the research consent forms. Results and consent forms will be kept in a locked filing cabinet on the University of Auckland premises accessible only to the researchers participating in the study. Electronic data will be stored on a password protected University of Auckland computer, backed up by a server. Data will be destroyed after a period of six years by shredding and deleting computer files. De-identified results will be kept in a spreadsheet indefinitely.

Decision to participate and the right to withdraw at any time

Participation is entirely voluntary. If you decide that you, your child and your child's teacher can participate, you are free to withdraw your support for this research at any time without having to give a reason and without consequence. You may withdraw results up to three months after you, your child and your child's teacher begin to participate in the study.

How to Contact Us

If you have any questions, please feel free to contact us (contact details below).

After completion of the study a summary of the findings will be made available on request.

Contact details of researchers

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Email: sc.purdy@auckland.ac.nz

Dr William Keith
Senior Research Fellow
University of Auckland
Director

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Professor Ian Kirk
Acting Head
School of Psychology
The University of Auckland
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Email: i.kirk@auckland.ac.nz Dr Will Hayward

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Tel: (09) 9235221
c.mccann@auckland.ac.nz

Dr Jane Carroll
Senior Researcher
University of Otago
Jane.carroll@otago.ac.nz
Tel: (03) 479 5267

Ethics approval: For any queries regarding ethical concerns you may contact:
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The University of Auckland Human Participants Ethics Committee
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Email: ro-ethics@auckland.ac.nz

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE ON 23 August 2017 FOR THREE YEARS. Reference number 019449

Appendix L History Form

SCIENCE
SCHOOL OF
PSYCHOLOGY

Speech Science
School of Psychology, Faculty of Science
THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Email: l.sparshott@auckland.ac.nz

HISTORY FORM

THIS FORM WILL BE HELD FOR A PERIOD OF SIX YEARS

Project Title: Phonological Processing Treatment: Diagnosis and Remediation of Auditory Processing Disorder in Children

Researchers: Lucy Sparshott, Suzanne Purdy, William Keith, Melissa Baily, Clare McCann, Jane Carroll

Thank you for agreeing to participate in our study. Please complete these background questions.

Child's Name: ....

Child's DOB: …………………………………………………….

Parent's Name: ....

Email address: ………………………………………………………………………

Phone number: …………………………………..

1. Date of APD test: …………………………………..

2. Clinic where APD test done: ……………………………………………….

Please attach most recent report

3. Has your child experienced any of the following? Please add comments and tick the relevant box.

Diagnosis/difficulty	Yes	No	Not sure
Diagnosis/difficulty with cognitive, learning, attention, ,memory skills (Please attach most recent report) Comments:			

Diagnosis/difficulty with literacy/reading/spelling (or dyslexia) Comments:			
Diagnosis/difficulty with behavior Comments:			
Social communication difficulties or autism Comments:			
Suspicion or diagnosis of speech/ language delay or disorder or other (please state) Comments:			

4. Is English spoken at home? Yes / No

5. Is there more than one language spoken at home? Yes / No

Main language spoken at home: ____

Other languages spoken at home: ____

Ethnicity of child:____

6. Has your child been involved in any music training outside school? Yes / No

Please specify:____

7. Has your child been involved in any speech or language training? Yes / No

Please specify: ____

8. Has your child ever worn hearing aids or used any other amplifying device? Yes / No

Please specify:

____

Thank you for your help!

I have attached/included my child's most recent reports:

- o **Auditory processing disorder report**
- o **Cognitive skills/Educational psychology report**

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE ON 23 August 2017 FOR THREE YEARS. Reference number 019449

Appendix M Information for Parents not at SoundSkills including APD test

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

SCIENCE
SCHOOL OF PSYCHOLOGY

Speech Science
School of Psychology, Faculty of Science
THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Email: l.sparshott@auckland.ac.nz

PARTICIPANT INFORMATION SHEET FOR PARENTS/CAREGIVERS

Project Title: Phonological Processing: Diagnosis and Remediation of Auditory Processing Disorder in Children

Researchers: Lucy Sparshott, Suzanne Purdy, William Keith, Melissa Baily, Clare McCann, Jane Carroll

The Project

The purpose of this project is to find a useful treatment method for improving the listening skills of children with Auditory Processing Disorder (APD). We want to compare some clinical tests and treatment methods for listening to work out which are the best tools to use with children with APD. In particular we will focus on testing and training phonemic awareness, which is the ability to identify and manipulate the small sounds of speech (phonemes).

The ability to process the more complex parts of a language is called phonological processing. These skills including phonemic awareness, are important for children to learn to read, write and spell well (literacy). Difficulties with phonological processing are often seen for children with APD.

Families with school-aged children who have been diagnosed with APD will be asked to participate.

This research is part of a two-year project that started in September 2016 and will finish in September 2018. It is being conducted in partnership with SoundSkills APD clinic, a specialist centre for diagnosis and treatment of APD, based in Greenlane, Auckland. The Oticon Foundation (Denmark) has provided funding for this research.

Participants

We are looking for children who have a diagnosis of auditory processing disorder (APD), a normal audiogram (pure-tone hearing test) and normal cognitive skills who are aged between 5-9 years old. Your child must have a recent diagnosis of APD (in the past year).

What will be done

APD and cognitive testing may be required for your child if any of the following apply:

- if your child has not previously been tested for APD

- if it has been some time since your child has had an APD diagnosis (more than 15 months)
- if the APD assessment your child received does not meet our criteria
- if your child does not have recent cognitive assessment information.

The cognitive testing requires your child to look at and match patterns (it is a non-verbal test). For the APD testing she/he will be asked to undergo further testing which will require your child to repeat numbers and words. If the cognitive/APD testing shows that your child does not have APD or has a hearing/cognitive disorder then we cannot include her/him in the research project. Your child will then not be eligible to continue in the research project. However, a report will be provided to you after the testing outlining the results and recommending referrals if required. The total testing time will be 30 minutes for hearing testing only or approximately 2 to 2 ½ hours for hearing and APD/cognitive testing.

Once it is clear your child has a diagnosis of APD and does not have cognitive/hearing problems we will ask him/her to attend another appointment to undergo some extra tests including tests of phonological processing skills, listening, reading, and spelling for the research project. Your child will be asked to repeat sounds, words, numbers and sentences. She/he will also be asked to read and spell words and discuss the meaning of words and/or short passages. This testing appointment will last 2 hours.

All testing will be carried out at SoundSkills APD clinic, located at The Stichbury Bidwill Centre, 251 Campbell Road, Greenlane, Auckland

There will be no charge for any of the appointments. All of the tests will be carried out using procedures routinely used in testing children. Testing will be conducted by the researchers and by clinic audiologists who have signed a confidentiality agreement.

We will also ask you to complete a questionnaire about your child's functioning in everyday life. This questionnaire may be available online or in paper format, and will take 10-15 minutes to complete. If you agree, your child's teacher will also be asked to complete a questionnaire about your child's functioning at school. We may also ask your child to complete a questionnaire about her/his experiences of hearing in different environments.

We also would like your permission to access your child's recent academic performance assessment data (the principal of the school's permission will also be gained on a separate form).

The researchers will also require information if available from your child's APD diagnostic reports, hearing tests and other relevant reports, e.g. from speech language therapists or educational psychologists. A brief background history of your child will also be obtained prior to testing.

Please note that we are not able to offer a complete service regarding diagnosis and management of APD for your child as we will only offer the testing that is required for the research project. If you would like to consider APD management options for your child after the study if required, we recommend that you contact SoundSkills clinic.

After the testing appointment, your child will be randomly assigned to one of three therapy groups. All groups will attend a therapy appointment for approximately 1 hour per week for up to 15 weeks. Two groups will receive therapy immediately with one group receiving therapy with mild amplification (using a headphone device providing extra volume of the therapist's voice). The third group (control group) will receive therapy after a delayed period of 15-20 weeks.

At the end of the 15 week period, all children will undergo repeat testing of the same tests originally performed during the first test appointment. This second test is very important to determine if there has been any change to your child's skills over the 15 week period. This testing will again be carried out at SoundSkills APD clinic at no charge in an appointment lasting up to 2 hours.

Children in the control group will also be asked to repeat testing for a third time after they have received therapy.

The researchers will require information from your child's APD diagnostic reports, hearing tests and other relevant reports, e.g. from speech language therapists or educational psychologists.

Benefits

Your child may receive extra testing of her/his hearing, auditory processing, cognitive, reading, spelling, listening and phonological processing skills. The testing may identify previously overlooked areas of difficulty that can be addressed in treatment or further referral. You will receive a report outlining the results of the hearing and APD testing (if undertaken) and recommending any referrals if required.

If your child meets the inclusion criteria he/she will also receive free treatment aimed at improving phonological processing skills which may have a flow-on effect to improve her/his listening for literacy.

Costs

There are no additional charges from SoundSkills or the University of Auckland for your child to undergo these assessments and treatment.

Incidental Findings

There is the potential that the testing and questionnaires may highlight areas that have not been previously detected. The researchers are experienced clinical professionals who will be able to discuss any concerns you may have and will be able to refer if needed. Further audiological support is available through hospital audiology clinics, the University of Auckland Hearing and Tinnitus Clinics and SoundSkills APD clinic.

Confidentiality

The information provided by you, your child and your child's teacher in this study will remain confidential and no information that will identify you, your child or your child's teacher as an individual will be reported in any reports, presentations or publications. Only the researchers will have access to the data files.

Storage of information

Results will be held in a separate place to the research consent forms. Results and consent forms will be kept in a locked filing cabinet on the University of Auckland premises accessible only to the researchers participating in the study. Electronic data will be stored on a password protected University of Auckland computer, backed up by a server. Data will be destroyed after a period of six years by shredding and deleting computer files. De-identified results will be kept in a spreadsheet indefinitely.

Decision to participate and the right to withdraw at any time

Participation is entirely voluntary. If you decide that you, your child and your child's teacher can participate, you are free to withdraw your support for this research at any time without having to give a reason and without consequence. You may withdraw results up to three months after you, your child and your child's teacher begin to participate in the study.

How to Contact Us

If you have any questions, please feel free to contact us (contact details below).

After completion of the study a summary of the findings will be made available on request.

Contact details of researchers

Lucy Sparshott
Research Fellow
Discipline of Speech Science
The University of Auckland
Private Bag 92019
Auckland 1142
Tel: (09) 923 6659
Email: l.sparshott@auckland.ac.nz

Dr Suzanne Purdy
Head of Speech Science
The University of Auckland
Private Bag 92019
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Tel: (09) 923 2073
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Dr William Keith
Senior Research Fellow
University of Auckland
Director

SoundSkills APD Clinic
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Melissa Baily
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Professor Ian Kirk
Acting Head
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Auckland 1142
Tel: (09) 923 8524
Email: i.kirk@auckland.ac.nz Dr Will Hayward

Clare M McCann (PhD)
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Tel: (09) 9235221
c.mccann@auckland.ac.nz

Dr Jane Carroll
Senior Researcher
University of Otago
Jane.carroll@otago.ac.nz
Tel: (03) 479 5267

Ethics approval: For any queries regarding ethical concerns you may contact:
The UAHPEC Chair
The University of Auckland Human Participants Ethics Committee
The University of Auckland, Research Office
Private Bag 92019, Auckland 1142
Tel: 09 373-7599 extn. 83711
Email: ro-ethics@auckland.ac.nz

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE ON 23 August 2017 FOR THREE YEARS. Reference number 019449

Appendix N Consent form for Parents not at SoundSkills including APD test

SCIENCE
SCHOOL OF
PSYCHOLO

Speech Science
School of Psychology, Faculty of Science
THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Email: l.sparshott@auckland.ac.nz

CONSENT FORM FOR PARENTS/CAREGIVERS

THIS FORM WILL BE HELD FOR A PERIOD OF SIX YEARS

Project Title: Phonological Processing Treatment: Diagnosis and Remediation of Auditory Processing Disorder (APD) in Children

Researchers: Lucy Sparshott, Suzanne Purdy, William Keith, Melissa Baily, Clare McCann, Jane Carroll

The research project has been explained to me and I understand the purpose of my (and my child's) participation. I have had the opportunity to ask questions and have them answered to my satisfaction.

- I have read and I understand the information sheet.
- I understand that researchers will require information from my child's APD diagnostic reports, hearing tests and other relevant reports, e.g. from speech language therapists or educational psychologists.
- **I understand that in order to participate in this research project my child may be required to undergo diagnostic hearing, cognitive and APD testing at SoundSkills clinic taking approximately 2-2½ hours.**
- **I understand that if this testing shows that my child does not have APD, has cognitive/ hearing disorders he/she will not undergo any further testing/treatment as part of this research. However, I will receive a report with recommendations for further tests and referrals if required. Further advice may be offered by the researchers if requested.**
- I understand that the researchers may ask the school to provide recent academic performance scores for my child.
- I understand that my child will be required to attend a testing appointment at SoundSkills for approximately 2 hours on two or three occasions.
- I understand that my child will be asked to do tests for: phonological processing skills, reading, spelling, and hearing for complex speech.
- I understand that my child, my child's teacher and I will be asked to complete a questionnaire that will take approximately 10-15 minutes to complete on two or three occasions.
- I understand that my child will be randomly assigned to one of three therapy groups.
- I understand that the therapy will involve my child attending SoundSkills clinic for an hour per week for up to 15 weeks.

- I understand that it is my choice and my child's choice to participate or not to participate.
- I understand that I may withdraw my information and my child's information from the study up to three months after completion of the treatment by contacting one of the researchers listed above. If I do withdraw all information relating to my and my child's participation will be withdrawn and will not be included in any reports.
- I understand that if the information I and my child provide is reported/published, this will be done in a way that does not identify me or my child as its source.
- I understand that consent forms and information collected during this study will be stored in locked filing cabinets at the University of Auckland and electronic data will be stored on a password protected University of Auckland computer, backed up by a server. Data will be destroyed after a period of six years by shredding and deleting computer and audio files. De-identified results may be kept in a spreadsheet indefinitely.
- I know whom to contact if I have any questions about the study.

If you would like to participate, please complete this form and return it in the enclosed envelope.

I _________________________________(parent/caregiver full name) agree to participate and that this may involve my child undergoing diagnostic hearing, cognitive and APD testing to be included in this study

I ____________________________________ (parent/caregiver full name) understand that if my child does not have receive a diagnosis of APD they can not participate in further assessment or therapy.

Consent of participants under 16 years is to be obtained through a parent or legal guardian.

I, the parent/legal guardian of _______________________________________(child's first and last name) agree for my child to participate in the study.

I agree to my child's teacher being asked to participate in this research: Yes / No

I agree to my child's academic performance scores being released to the research team Yes/ No

(If your answer is yes please provide the name of your child's teacher and school)

Teacher's name and School:

____

I would like to receive a summary of the research upon completion: Yes / No

(If your answer is yes please provide an email address that you would like the summary sent to)

Email Address: ____

Parent/Caregiver name (please print)____

Parent/Caregiversignature____Date____

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE ON 23 August 2017 FOR THREE YEARS. Reference number 019449

Appendix O Template of PPT Assessment Report

SCIENCE
SCHOOL OF
PSYCHOLOGY

Speech Science
School of Psychology, Faculty of Science
THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Email: l.sparshott@auckland.ac.nz

Phonological Processing Treatment: Diagnosis and Remediation of Auditory Processing Disorder in Children.
A collaborative research project conducted by the University of Auckland, SoundSkills APD clinic and Oticon Foundation, Denmark

Assessment Report 1

Re:
DOB: Age at assessment:
Date of Assessment:

BACKGROUND

Child took part in hearing and language based assessments as part of their involvement in a research project conducted by the University of Auckland in collaboration with SoundSkills APD clinic. The testing was done at The University of Auckland (Tāmaki Campus) in a sound-proof room by a Speech language therapist (the university researcher) and took around 2 hours. A break was provided half way through testing.

Please note that these tests will be conducted twice for the purposes of the research therefore this is Assessment Report 1. The same battery of tests will be repeated after 12 sessions of phonological therapy provided by a Speech language therapist. Those results will be provided in Assessment Report 2.

In order to take part in the research a diagnosis of Auditory Processing Disorder by an audiologist was required.

The test results are summarized below. Explanations of the tests are appended.

RESULTS OF ADDITIONAL TESTS REQUIRED FOR RESEARCH PROJECT

Hearing Screening showed essentially normal hearing in both ears within screening limits, and normal middle-ear function in both ears (Type A tympanograms).

1. **Bamford-Kowal-Bench Speech-in-Noise Test (BKB-SIN)**
   (Average SNR-50) score =

2. **Test of Phonological Processing (CTOPP-2)**

Subtest name	**Raw score**	**Scaled Standard Score**
Elision		
Blending words		
Phoneme Isolation		
Memory for digits		
Nonword repetition		
Rapid digit naming		
Rapid letter naming		

3. **Test of Narrative Language (TNL-2)**

	Raw Score	**Scaled Score**
Comprehension		
Production		

4. **Wheldall Assessment of Reading Passages (WARP)** Reading passage 2

Words correct per minute (wcpm) =

5. **South Australia Spelling Test**

Score	**Approximate spelling age range**

6. **Letter-Sound Test (LeST)**

Score	**z-score**	**Classification**

The tests were completed in one session.

FINDINGS

These results show strengths in:

- Z tests .

Scores on P tests were below average range:

-

We are not able to offer any further service regarding diagnosis and management of APD for your child as we only offer the testing and treatment that is required for the research project. If you would like to consider APD management options for your child after the study we recommend that you contact SoundSkills clinic.

Thank you for your participation. We really appreciate your support for this research which will help to define treatment recommendations for children with APD in New Zealand.

Yours sincerely

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DESCRIPTION OF TESTS

1. **Bamford-Kowal-Bench Speech-in-Noise Test (BKB-SIN)**

The BKB-SIN is a speech-in-noise test that measures the child's ability to hear short sentences when there is competing background noise. The noise in the background gets louder and the child needs to listen harder to hear. A higher score indicates more difficulty hearing in noise.

Score (average SNR-50)	**Range**
-0.4 to 2.0	Normal range for age
2.1 to 3.2	More difficulty hearing in noise
3.3 and above	Significant difficulty hearing in noise

2. **Comprehensive Test of Phonological Processing**

The CTOPP-2 is a norm-referenced test that measures phonological processing abilities related to reading.

Elision measures the ability to remove phonological segments from spoken words to form other words.

Blending words measures the ability to synthesize sounds to form words.

Phoneme Isolation measures the ability to isolate the individual sounds within words.

Memory for digits measures the ability to repeat numbers accurately

Nonword repetition measures the ability to repeat non-words accurately

Rapid digit naming measures the ability to rapidly name digits

Rapid letter naming measures the ability to rapidly name letters

<u>Descriptive Terms for CTOPP-2 Scaled Scores</u>

Scaled scores are subtest scores converted from raw scores which provide an indication of a child's subtest performance based on a normal distribution.

Scaled score	**Descriptive term**
17-20	Very superior
15-16	Superior
13-14	Above average
8-12	Average
6-7	Below average
4-5	Poor
1-3	Very poor

3. Test of Narrative Language (TNL-2)

This test measures children's narrative ability (how they understand and tell stories) which is an important aspect of spoken language**.** The 'comprehension' score measures understanding of the story. The 'production' score shows the child's ability to tell a story. This is a US test and the scaled score shows the child's ability compared to a normal distribution of children of a similar age.

Subtest scaled score	**Descriptive term**
17-20	Very superior
15-16	Superior
13-14	Above average
8-12	Average
6-7	Below average
4-5	Poor
1-3	Very poor

4. Wheldall Assessment of Reading Passages (WARP)

The WARP is an Australian test of reading passages that has been shown to:
- identify low progress readers
- track reading progress over time

The score a child receives is based on how many correct words they read in a minute (wcpm). The WARP offers 'benchmarks' for the mean (average) score for the school year. These are NOT standardized scores, but extrapolated approximates only.

Australian school Grade	Average age	Average range of (wcpm) scores across the year	Bottom quartile (25%) range scores across the year
2	7 ½	57-82	31-51
3	8 ½	86-100	56-73
4	9 ½	107-123	80-98
5	10 ½	125-132	101-110

5. South Australia Spelling Test

An Australian standardized test in which the child is asked to spell up to 70 words (they are stopped when they make 10+ errors in a row) and their score is compared to the typical scores of children in their age range.

6. Letter-Sound Test (LeST)

This Australian normed assessment tells us the child's knowledge of the sounds/phonemes that letters/graphemes make.

The z-score is a standard score with a mean of 0 and a standard deviation of 1.

z-score range	**classification**
+2 and above	Well-above-range
+1 to +2	Above-average range
-1 to +1	In-the-average range
0	Average performance
-2 to -1	Below-average range
Below -2	Well-below-average range

Appendix P BKB-SIN List pair 2A and 2B

LIST PAIR 2

List 2A	Key Words	# Correct	SNR
1. The cat is sitting on the bed.	4	______	+21 dB
2. They had a lovely day.	3	______	+18 dB
3. The thin dog was hungry.	3	______	+15 dB
4. They are watching the train.	3	______	+12 dB
5. The dog played with a stick.	3	______	+9 dB
6. The farmer keeps a bull.	3	______	+6 dB
7. The lady wore a coat.	3	______	+3 dB
8. The boy is running away.	3	______	0 dB
9. The room is getting cold.	3	______	-3 dB
10. The wife helped her husband.	3	______	-6 dB

Total Key Words Correct ______

SNR–50 = (23.5) - (# Correct) = ______dB

List 2B	Key Words	# Correct	SNR
1. The lady went to the store.	4	______	+21 dB
2. A tree fell on the house.	3	______	+18 dB
3. The fruit came in a box.	3	______	+15 dB
4. The husband brought some flowers.	3	______	+12 dB
5. A man told the police.	3	______	+9 dB
6. Potatoes grow in the ground.	3	______	+6 dB
7. The big dog was dangerous.	3	______	+3 dB
8. The strawberry jam was sweet.	3	______	0 dB
9. The boy has black hair/tie.	3	______	-3 dB
10. The mother heard the baby.	3	______	-6 dB

Total Key Words Correct ______

SNR–50 = (23.5) - (# Correct) = ______dB

Average SNR–50, Lists 2A and 2B = ______dB

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